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THE JOURNAL OF THE FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS,

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Under the Direction of the Committee on Publication.

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PHILADELPHIA:

FRANKLIN INSTITUTE, No. 15 SOUTH SEVENTH STREET.

1877.

JOURNAL OF THE FRANKLIN INSTITUTE,

VOL. CIV.

INDEX.

ERRATA.

Read authors' names in Book Notices, on page 232, John H. Cooper; and on page 375, S. Edward Warren.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

Vol. CIV. JULY, 1877. No. 1.

Franklin Institute.

Hall of the Institute, June 20th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 104 members and 7 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at their last meeting, the action of the Committee on Science and the Arts, recommending the award of the Elliott Cresson Gold Medal to John Charleton, for his Internal Clamp Coupling; and the Scott Legacy Premium and Medal to Thos. Shaw, for his Spiral Exhaust Nozzle, was approved; and that these medals will be awarded and delivered to said parties at the end of three months, unless, within that time, satisfactory evidence of want of originality be lodged with the Actuary. Also, that 8 persons were elected members of the Institute, and the following donations were made to the library:

Plano Telegrafico de la ysla de Cuba, por D Eurique de Arantave.

Annals of the Astronomical Observatory of Harvard College. Vol. 1, Pt. 1, to Vol. 4, Pt. 1, and Vol. 5. From Harvard College Observatory.

Specifications and drawings of Patents issued from the United States Patent Office, for November, 1876. From the office.

The Queenslander. Brisbane, February 17th, 1877. From Hector Orr.

Report of progress in the Counties of York, Adams, etc., etc., by Persifor Frazer, Jr. Harrisburg, 1877. 2d geological survey of Pennsylvania, 1875.

Report of progress in the Cambria and Somerset district of the Bituminous coal fields of Western Pennsylvania, by F. & W. G. Platt. Pt. 1, Cambria. Harrisburg, 1877.

Special report on the Coke Manufacture of the Youghiogheny river valley, by F. Platt. Harrisburg, 1876.

From the Board of Commissioners of the Survey.

Narrow gauge locomotives. Baldwin Locomotive Works. Philadelphia, 1877.

Exhibit of locomotives, by Burnham, Parry, Williams & Co Philadelphia, 1876. From the Works.

Verhandlungen des Naturhistorisch, Medicinischen Verein zu Heidelberg. 5th Pt., 1st Vol., New Ser., 1877. From the Union.

Catalogue of chemicals, chemical apparatus, etc. 13th Edition, 1876. From Bullock & Crenshaw.

Report of the joint committee (of the Ohio Legislature) concerning the Ashtabula bridge disaster, 1877. From M. Barnes, Secretary of State.

On a peculiar type of eruptive mountains in Colorado, by A. C. Pearle, M.D. From the Author.

Contributions to the Centennial Exhibition, by John Ericsson, New York. From the Author.

Fifty-seventh anniversary celebration of the Mechanic Apprentices' Library Association, in Mechanics' Hall, February 22d, 1877. Boston, Mass. From the Association.

Supplement to the report of the Permanent Committee of the first Intern. Congress, at Vienna. From the Meteorol. Com. Royal Soc.

Geological exploration of the 40th parallel, made by order of the Secretary of War, by C. King. From the Engineers' Dept., Wash.

Map showing the relative preponderance of Nationalities in Turkey.

Schedler's map of the Black Sea, Asia Minor, etc., etc.

Schedler's maps of Dobrudsha, Central Roumania and Bessarabia, also of Western Bulgaria, Roumania, etc., with a special map of the seat of war in Asia Minor.

Schedler's map of Turkey and Greece.

From Charles Bullock.

Kentucky Geological Survey. Resources of Kentucky.

Bayer & Co. Barmen und Elberfeld.

Bicarbonate of Soda. Penna. Salt Manuf. Co.

Le Chili, tel qu'il est. 1876.

Descriptive Catalogue of collection of economic minerals of Canada, etc., etc. 1876.

Catalogue of the Chilian Exhibit, at Centennial Exhibition, 1876. From Prof. Thomas, N. J.

Annual report of Friends' Free Reading Room and Library. Germantown, 1877. From the Librarian.

Report of the U. S. Commission of Fish and Fisheries. 1873–75. Washington. From the Smithsonian Institution.

Seventh annual report of the Board of Commissioners of Public Charities of the State of Penna. Harrisburg, 1877.

Report of the Transactions of the Penna. State Agricultural Society, for 1876. Vol. II. Harrisburg, 1876.

Annual report of the Secretary of Internal Affairs, of the Commonwealth of Penna., for 1876. Pt. 1, Land office, Pt. 2, Assessments. Harrisburg, 1877.

From A. K. Dunkel.

Minutes of Proceedings of the Institution of Civil Engineers. Vol. 48. Sess. 1876–77. Pt. 2. London, 1877. From the Institution.

Report on a developing school and school shops, by a committee appointed by the American Social Science Association. Boston, January 10th, 1877. From the Association.

On repulsion resulting from radiation. Preliminary note on the Atheoscope, by Wm. Crookes. London, 1877. From the Author.

Account of the manners of the German inhabitants of Pennsylvania, written 1789, by B. Rush. Notes added by Prof. I. D. Rupp. Phila., 1875. From Prof. Rupp.

[Donations continued in next number.]

The following papers were then read: one by Mr. S. F. Gates, on Weights and Measures, read by the Secretary; and one by Mr. J. T. Wainwright, read by the author.

Mr. Robert Briggs, in a note, wished the Secretary "to bring to the "attention of the members present, an exhaustive article of mine in "the JOURNAL for April, 1876,[i] which I think covers the effect of "extra length in steam boilers, with much completeness, as well as "showing the resulting effect on the draft of the chimney."

Mr. J. W. Nystrom called attention to the exhaustive experiments made by the Société Alsacienne de Construction Mechaniques of Mulhouse, in which the boiler having the least heating surface gave the best results.

The Secretary presented his report embracing the following subjects: Lieut. C. A. L. Totten's Compensating-Powder for heavy artillery[ii]; E. LeFranc's Decorticator for ramé, jute, hemp, etc.; Mr. J. H. Cooper's Mechanical Movement for changing continuous rotary motion into intermittent rotary motion; a Balance Slide Valve by the same inventor; Dr. F. J. Delker's Water-Filter; and a note on the Traction of Locomotives.

The President called the Vice-President to the chair, to make some remarks, and the latter presided during the remainder of the meeting.

Mr. J. B. Knight, representative of the Franklin Institute in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, presented a report of the progress making by that institution.[iii]

A note from Mr. Robert Briggs was read, calling attention to a premium offered by the American Philosophical Society, for a process for successfully utilizing anthracite coal-dust.

The Secretary gave notice that as the time for the next stated meeting of the Committee on Science and the Arts, falls on the 4th of July, the meeting has been adjourned to the first Wednesday in August next.

Prof. J. Ennis offered a series of preambles and resolutions upon the subject of teaching "science in common schools and by public lectures," which, on motion of Dr. Rogers, amended by Mr. Orr, were referred to the Committee on Primary Industrial Education.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

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[i] JOUR. FRANK. INSTITUTE, 3d Series, Vol. lxxi, p. 246.

[ii] See page 54.

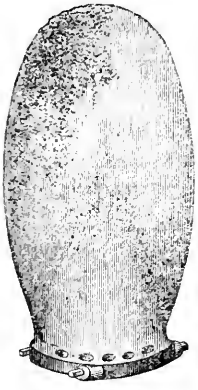
[iii] See page 6.

CORROSION OF PROPELLER BLADES.

Extract from the Secretary's Report, at the Meeting of the Franklin Institute held May 16th, 1877.

Your attention is called to a remarkable corrosion of the cast iron propeller blades of transatlantic steamers, by these pieces taken from one of the American Line ships, and to this image projected on the screen, of another blade, showing its peculiar location.

The view shown is the forward or following side of the blade, and the corroded portion is next the entering edge, and extends about half the width of the blade at the outer end, and to an irregular line drawn diagonally across to the entering edge, about half its length. Along the edge, however, there is a space about $1\frac{1}{2}$ inches wide, which is not at all corroded. About 20 inches from the outer end, and midway of the width of the blade, is a hole $1\frac{1}{2}$ inches diameter used for handling the blade, and through this the water passes when the propeller is in motion. The interior of this hole is not corroded, but the surface of the blade on the side opposite to the direction of its motion is deeply pitted, sometimes to the depth of half an inch. Nowhere else is there any appearance of corrosion, the paint on the remaining portion of the following side of the blade being still visible after three years' service, and that on the after or thrust-face being worn away by the friction of the water. In one case the outer end of the blade was eaten away to such an extent that a piece of about one square foot area, broke off by the action against the water, showing a thickness of solid metal of less than half an inch. These blades were made of No. 1 cold blast charcoal pig-iron, and were cast with the now corroded face downwards. Eleven of these have been broken up for smelting, and there is no evidence of imperfections in the casting. The propellers from which they were taken are 17 feet diameter, 24 feet pitch, and make 60 revolutions when in service; the width of the blade is $3\frac{1}{2}$ inches. This action is found on all steamers making transatlantic voyages, but has not been observed on our coastwise steamers.



What is the cause of this corrosion, and why it always selects this particular spot for its action, are very interesting questions. K.

THE PENNSYLVANIA MUSEUM AND SCHOOL OF INDUSTRIAL ART.

Report of the Representative of the Franklin Institute, at the Meeting held June 20, 1877.

Since my last report in January last,[1] arrangements have been perfected by which the Museum authorities have been placed in formal possession of Memorial Hall; and with a sum of money appropriated by the Centennial Board of Finance, the building has been put in condition to receive the collections of the Museum. These collections, the nucleus of which was formed at the Centennial, have been materially increased by purchases since made, and by loans from Europe.

Two leading London firms have sent, on loan for one year, representative collections; one of English pottery, and the other of French pottery and glass. These additions to the collection of works already owned by the museum, together with the collection of Spanish pottery and glass loaned by Signor Riaño, make the department of ceramic and glass work almost complete, and present a valuable opportunity of study to our potters and glass-makers, which, if taken advantage of, will tend to greatly improve those important and growing industries.

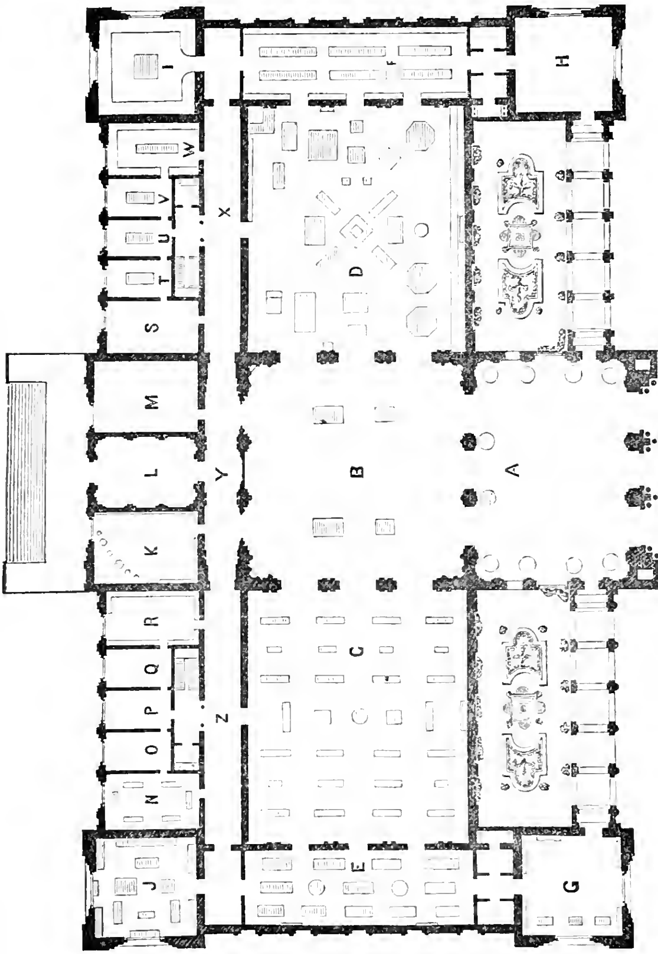
The works in the precious metals, with the electrotype reproductions, are, together with the ceramic and glass objects, placed in the large west gallery, C. There is also in this room the collection of Persian art, selected with great care, in Persia, by Mr. Caspar Clarke, and presenting the application to various materials of the deservedly admired Oriental design and coloring.

In the west saloon, E, the India collection is arranged in its entirety, comprising a complete collection of specimens illustrating the products and manufactures of India.

The northwest pavilion, J, is devoted to the textile fabrics and embroideries. This department has been also greatly added to, and now contains valuable specimens of various ages, most important as studies for the designer and manufacturer. In the southwest pavilion, G, there are now being arranged the specimens of wood-work, iron-work, casts of architectural ornament, and all that relates to the subject of art applied to building and the construction of domestic articles.

[1] See Vol. ciii, page 85; February, 1877.

Along the walls of the west corridor, Z, is hung the framed material, consisting of drawings, lithographs, and photographs of art objects, which, in the absence of the originals, suffice to instruct the student and interest the casual visitor. The rooms opening on the corridor will be utilized as follows: M contains miscellaneous objects,



The Pennsylvania Museum and School of Industrial Art

on loan; O, P, Q, offices; R, the library and room for consultation of works of reference. The rotunda, B, is reserved for the larger objects of the various collections, as the light is so high that smaller specimens could not well be studied.

The entire eastern portion of the building has been set apart for the display of the collections of the American Institute of Mining Engineers, and will shortly be opened to the public.

As the arrangement of mineral and metallurgical specimens rapidly progresses, it becomes more and more evident that they will form the most valuable collection of the kind in this country, and its importance to the student cannot be overestimated. To the specimens of European production presented to the Institute at the Centennial, is added most complete illustrations of our own mining and manufacturing industries, giving an opportunity of comparison of materials and processes most instructive and important.

In order to facilitate the admission of visitors, an arrangement has been concluded with the Permanent Exhibition Co., by which tickets sold at either building admit to both the Main Building and the Museum and all other collections in Memorial Hall.

So soon as the collections of the Museum are arranged to the satisfaction of the officers, descriptive catalogues and handbooks will be published; in the meanwhile, a system of distinct labeling of the objects has been introduced.

The committee on instruction are engaged in preparing a plan for the schools, which, if sufficient financial support can be obtained, will be put in operation before the end of the year.

I am pleased to report, in conclusion, the practical and comprehensive character of all that has been so far accomplished in the establishment of the Museum, and to urge upon the attention of the members of the Institute the fact that the interests of the mechanic arts are so intimately involved in the Museum scheme, as to warrant the warmest interest and support.

J. B. Knight.

Simultaneous Meteorological Observations.—M. Alluard, director of the observatory of the Puy-de-Dôme, finds some remarkable changes in the differences of pressure indicated by self-registering barometers. One was placed on the summit of the Puy-de-Dôme and the other at Clermont-Ferrand, and on comparing the simultaneous records, discrepancies were found, which could neither be explained by the variations of temperature nor by Laplace's formulæ for the barometric determination of altitudes.—*Les Mondes*, April 19.

C.

CORRESPONDENCE.

NEW YORK, June 5th, 1877.

Editor of Franklin Institute Journal:

Having been shown a republication of a late controversy in the *Scientific American*, on the Force of Falling Bodies, I find that one of the parties has seen fit to adopt my formula therefor, whereupon an opponent is pleased to charge him with being "misled by Haswell," inasmuch as he had attained his result by the formula $W v \, 4{\cdot}426 = M$. I therefore feel called upon to defend the party who has confided in me, and I submit the following:

Having long entertained the conviction of the error of the ordinary formula for the computation of the impact of a body falling freely, I, in 1852, instituted a series of experiments, having in view a determination of the impact by actual operations; for a detailed report of them, see Appleton's *Mechanics' Magazine*, Vol. II, p. 281, the result of which established the following:

1st. That the dynamical effect, or measure of impact, is directly as the velocity acquired, or, that at the termination of the stroke.

2d. That one pound falling freely through a space of one foot, and having consequently a velocity of $\sqrt{1 \times 2\,g} = 8{\cdot}02$ feet per second, had an impact of 35·5 lbs., and that in falling 2 feet, having a velocity of $\sqrt{2 \times 2\,g} = 11{\cdot}34$ feet per second, had an impact of 50 lbs., and in like manner other weights, and at different heights of fall, furnished like results. Hence, $\frac{M}{W \times v}$ or $\frac{35{\cdot}5}{1 \times 8{\cdot}02} = 4{\cdot}426$.

A comparison of these results with those deduced by the various formulæ submitted in the discussion, and which embrace all that I recollect to have met with, presents the following:

Weight and Height of Fall.	FORMULÆ OF W. H. P. $W \times h = M$	G. M. T. $W \times v = M$	P. H. Vander Weyde. $W \times v^2 = M$.	J. W. Nystrom. $\frac{W \times h}{d} = M$	Experiment.
	LBS.	LBS.	LBS.	LBS.	LBS.
1 lb. falling 1 ft.	1	8·02	64·33	2	35·5
1 lb. falling 2 ft.	2	11·34	122·66	4	50

W representing the weight of the falling body, h the height or

space fallen through, v the velocity in feet per second, d the distance an impinged body, as a nail, would be driven in inches—in this case ·5 inch is assumed—and M the effect, or moment of the impact.

In the experiments referred to I did not essay to attain the exact factor or multiplier of the weight, whereby to compute the impact, as I well knew my instrument was not equal to the requirements, but my purpose was to ascertain what was the general relation between velocity and impact, and in this particular I claim to have succeeded; whether the factor was 4·426 or 4·5 times, it mattered but little. I had made a successful step in a right direction, and with sufficient accuracy to meet the demands of practical operations.

In consequence of the great variety of formulæ as presented above, and the confident manner in which they are set forth, I have been induced to renew my experiments, and I again submit them, with a knowledge of their integrity and of the correctness of their deduction.

It is to be regretted that my instrument necessitated the weight to be arrested by a cord, as the tension thereof was at the expense of the impact of the weight; but in order to remedy this so far as practicable, without the construction of an instrument capable of admitting the weight to fall freely, and to be arrested only at the termination of the stroke, I used cords of hard-laid and long-used fish-line, laid up *selvagee*, and very flexible.

What the exact factor is I know not, but my impression is it will be fully 5 times the velocity.

Respectfully,

Chas. H. Haswell, C. & M. E.

Microseismic Observations.—Father Bertelli, after discussing more than 20,000 observations, made from 1870 to 1875, reaches the following conclusions: The oscillations of isolated pendulums are generally parallel or perpendicular to the axes of valleys or mountain-chains. The oscillations are not dependent upon local vibratory movements, nor on the velocity or direction of the wind, nor on rains, nor on thermometric or electric changes. The tromometric movements are most vertical at the time of earthquakes. The positions of the sun and moon seem to influence the movements of the pendulums, but they are especially frequent when the barometer is low. C.

Aniline Black.—M. A. Rosenstiehl closes a historical note as follows: Whenever one wishes to obtain, economically and regularly, aniline black upon tissue, the simultaneous co-operation of a chlorate and of a metallic substance is indispensable. In practice, copper has been adopted for blacks, developed at a temperature of about 45° C., and iron for those which must undergo a steaming, or a temperature of 100°. But if the conditions of industrial labor are not imposed, an aniline black can be obtained upon tissue, without the aid of chlorates, or of a metallic substance, by the simple action of "nascent" or active oxygen. Blacks may likewise be obtained, independent of tissues, without the intervention of a metal, by the aid of chlorates; I have already proved that this fact has long been known. The work of M. Coquillion has just shown that, in this case also, the same result may be reached without chlorates. The fact observed by him is an elegant demonstration of the action of active oxygen upon aniline salts; it will, perhaps, enable us to obtain blacks derived from aniline in a state of greater purity, and to hasten the moment when we shall know their elementary composition, a question which, in view of its great interest, has been proposed for a prize by the Industrial Society of Mulhouse.—*Annales de Chimie et de Physique*, Aug., 1876. C.

Old Gallo-Roman Harbor.—At a very early date, the neighborhood of St.-Nazaire, between Ville-Halluard and Méans, formed a bay sown with islands. About the 5th century B. C., the bay of Penhouet was inhabited by a maritime population. This population, with dolichocephalous skulls, was contemporaneous with the aurochs and the stag; it used instruments and arms of horn, bronze, and stone. The bottom of the bay was then about four metres below the present low-water level. This harbor was probably the *Corbilo* of Polybius, cited by Strabo. In the 3d century of our era, the same banks were occupied by Gallo-Romans. The bay of Penhouet served again as a harbor, to which Ptolemy gave the name of *Brivates portus*, the port of Brivet. The bottom of the bay was then only one and a half metres below low water. Towards the 8th century A. D., the Brivet, meeting an obstacle in the muddy bed of Penhouet, changed its course at a distance of two kilometres above its mouth, and found a new outlet at Méans. These dates have been fixed by M. Al. Bertrand, by studying the mud-deposits.—*Acad. des Sciences*, April 9. C.

Berlin Pneumatic Dispatch.—The proposed pneumatic dispatch in Berlin embraces 26 kilometres of tube, and has 15 initial stations. The wrought iron tubes have a clear breadth of 65 millimetres, and lie about one metre below the surface of the ground. The letters and cards which are to be forwarded, have a prescribed size, and are enclosed in iron boxes, or cartridges, each of which can hold 20 letters or cards. In order that they may pack closely, they are covered with leather. From 10 to 15 cartridges are packed and forwarded at a time; behind the last cartridge is placed a box with a leather ruffle, in order to secure the best possible closure of the tube. At four of the stations are the machines and apparatus needed for the business. The forwarding of the boxes is effected either through compressed or rarefied air, or through a combination of the two. Steam-engines of about twelve horse-power are used for the condensation or exhaustion of the air. Each main station has two engines, which drive a compressing and an exhausting apparatus, the steam for each engine being furnished by two boilers. Large reservoirs are employed, both for the condensed and for the rarefied air. The former has a tension of about three atmospheres; the latter, of about 35 millimetres of mercury. The air, which is heated to 45° C. by the compression, is cooled again in double-walled cylinders which are surrounded by water. The velocity of the boxes averages 1000 metres per minute, and a train is dispatched every 15 minutes. Each of the two circuits is traversed in 20 minutes, including stoppages. The entire cost of the enterprise will be about 1,250,000 marks.—*Dr. Grüneberg, in Wochenschrift des Vereines Deutscher Ingenieure*, March 31. C.

Change of Cane Sugar into Glucose.—Mons. U. Gayon finds that raw sugars, like molasses, gradually exchange crystallizable for incrystallizable sugar, leading sometimes to a loss of 33 per cent. The change is accelerated by heat and moisture. It does not appear to be due to acidity but to a true fermentation.—*Acad. des Sciences.* C.

Phosphorescent Organic Bodies.—B. Radziszewski finds that the following bodies have the property of shining in the dark, as soon as they are put in contact with an alcoholic solution of caustic potash: hydrobenzamide, amarine, lophine, and the crude product of the action of alcoholic ammonia on benzile. C.

Rarchaert's Total Adherence Locomotive.—The scientific and technical portion of a late number[1] of the *Annales des Mines*, is wholly taken up by a memoir of M. Massieu, and a short note of the inventor, upon Rarchaert's "locomotive of total adherence and converging axles." The locomotive was first tried on a circuit of 58 kilometres, during which it behaved well in all points of view, reaching a mean velocity of 40 kilometres, and sometimes exceeding 50 kilometres per hour, on slopes of ·015 and in curves of 250 metres radius. After this trial, it was employed, for about two months, upon trains. M. Rarchaert finally obtained authority from the company to employ his machine on regular trains, under the charge of the company's engineers and stokers, the expenses being borne by him. This condition was so burdensome, that he terminated the trial at the end of a month. During that time the locomotive had traveled 4349 kilometres, and had satisfied all requirements without accident. It has since been employed on the road from Orleans to Chalons. M. Massieu and his principal subordinates carefully studied the details of construction and operation, and presented two successive reports, which he was invited, by the commission of the *Annales des Mines*, to embody in a single memoir, under the following heads:

1. Brief examination of the processes hitherto employed to facilitate the passage of locomotives on curves, with the more or less complete utilization of the adherence which their total weight can give.
2. Description of the apparatus.
3. Study of the apparatus in a kinematic point of view; examination of the conditions in which it can overcome the curves and irregularities of the track.
4. Study of the apparatus dynamically; examination of the causes which can impair its stability.
5. Comparison with other locomotives employed on secondary lines; results of the trials.
6. Examination of the objections against the use of a single and straight connecting rod.
7. Summary and conclusion.

The memoir covers 200 pages; M. Rarchaert's note, 12 pages. Both terminate with the following conclusion: "For a long time, the constructors of locomotives with a single motor, have tried to sepa-

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[1] 5th livraison for 1876.

rately realize, sometimes total adherence, sometimes flexibility; sacrificing, according to circumstances, one of these conditions to the other. Among those who have tried to realize them both at once, I am led to believe that M. Rarchaert is the one who has best, and even for the first time, practically succeeded." C.

Phosphor-Tin and Phosphor-Bronze.—Phosphorus and tin combine in the most varied proportions, but if there is more than five per cent. of phosphorus, the alloy is broken up when remelted. The proportion of 95 per cent. tin and 5 per cent. phosphorus is so stable, that it remains unchanged, however often it may be remelted. Its melting point is about 500° C. It imparts its own stability to the bronze, which is made by the addition of proper proportions of copper. The well-ascertained influences of phosphorus upon bronze are: 1. The removal of all the metallic oxides in the bronze, and the consequent prevention of flaws, greater compactness, and increased solidity. 2. Phosphorus has a hardening influence on copper and tin; hence, copper alloyed with phosphor-tin gives a much harder bronze than with the same quantity of common tin, or one equally hard, with one-half the quantity. 3. The phosphorus makes the bronze more fluid, and the castings sharper. 4. The phosphorus increases the resisting capacity of the bronze, both against atmospheric influences and against acids.

The experiments of the English Admiralty have shown that sheathing of phosphor-bronze withstands the action of sea-water nearly three times as long as the best copper sheathing. The Austrian phosphor-tin, with 5 per cent. or $2\frac{1}{2}$ per cent. of phosphorus, may be melted with copper precisely like common tin. Notwithstanding its high price, the bronze which is made from it is only about 8 per cent. dearer than common bronze, while it is 40 per cent. cheaper than the phosphor-bronze which is imported from England and Germany.—*Wochenschrift des Oester. Ingen.- u. Archit.-Ver.*, April 28. C.

Prevention of Boiler Scale.—Herr Clouth employs a caoutchouc lacquer, which prevents the adhesion of the sediment to the walls of the boiler, so that the scale can be easily removed. After the scaling the boiler is left bright and smooth. The lacquer does not injure the iron, for its ingredients are only linseed oil and india-rubber.—*Ibid.* C.

Utilization of Parchment-Paper Waste.—In the first April number of *Dingler's Polytechnic Journal*, C. O. Cech calls attention to the fact, that in the manufacture of parchment-paper, after the treatment with sulphuric acid there is a large amount of waste, which cannot be converted into paper, and which is commonly burned under the boilers. In a single factory this waste often ranges from 750 to 1500 kilogrammes per month. It is so rich in cellulose that it seems desirable to turn it to a more profitable use, and such use is suggested by the method introduced in 1857, by Roberts, Dale & Co., Warrington, for manufacturing oxalic acid by heating sawdust with caustic alkali. When the carriage of the waste is attended with small cost, it can probably be worked so as to yield a more profitable return than Tessié du Motay's patent method[i] for making oxalic acid from turnips, or the process of Possoz[ii] for preparing it from wheat bran. The factory of Dr. Kunheim, in Berlin, which yearly makes 200 tons of oxalic acid from sawdust, has undertaken to give M. Cech's plan a thorough trial. C.

Acidity of the Gastric Fluid.—From experiments, by means of a gastric fistula, M. Ch. Richet concludes that: 1. The mean acidity of the gastric juice, whether pure or mixed with food, is about equivalent to 1·7 gr. of chlorhydric acid for 1000 gr. of liquid. He has never found the acidity less than ·5 gr. or greater than 3·2 gr. 2. The quantity of liquid in the stomach has no influence on its acidity; whether the stomach is nearly empty or overloaded with food, the acidity is nearly invariable. 3. Wine and alcohol increase the acidity; cane-sugar diminishes it. 4. If acid or alkaline liquids are thrown into the stomach, the gastric liquids tend very rapidly to recover their normal acidity, so that, by the end of an hour, the mean acidity is nearly restored. 5. The gastric fluid is most acid while digestion is going on. 6. The acidity increases slightly towards the end of digestion. 7. The sensations of hunger and thirst do not depend either upon the acidity or upon the fulness of the stomach.

C.

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[i] *Bull. de la Soc. chimique*, 1874, p. 187.

[ii] *Wagner Jahresbericht*, 1858, p. 110.

Phonetic Shorthand at the Franklin Institute,

2 1876 … 1877 … 200 … 29 … 25 … 13 …

[E. Alexander Scott.]

[D. Shepherd Holman]

[Moses J. Lobo]

[James A. Kirkpatrick]

[Franklin E. Paige]

[John Haug]

[Daniel Carhart]

… 4 …

… 25 …

[Joseph Thomas L L.D.] …

[Hector Orr] …

ON THE PRODUCTION AND USE OF COMPRESSED AIR IN MINING OPERATIONS.

By M. F. L. Cornet, Chief Engineer of the Mines of Eastern Flenu à Cuesmes, Cor. Member of the Scientific Section of the Royal Academy of Belgium.

[Translated from the French by Robert Zahner. Department of Engineering, Stevens Institute of Technology.]

[Continued from Vol. ciii, page 413.]

We have seen that it is water-spray that we propose to use for the absorption of heat during compression.

We would use the same means to provide the compressed air, at the time of its expansion, with the heat necessary to keep its temperature from falling below that of melting ice.

We admit, *a priori*, that, whatever be the quantity of heat contained in the air at the moment of its exit from the compressor, the cooling which it undergoes in the reservoir always restores its temperature to that of the atmosphere, *i. e.* to 20° C.

A cubic metre of atmospheric air, compressed to a tension of eight atmospheres, will yield, if expansion follows Mariotte's law, 31,756 kilogrammetres of work, of which 10,334 kilogrammetres are employed in overcoming atmospheric pressure. This work resolves itself into:—

(1.) The part realized at full pressure. This equals

$$10334 \times 8 \times 125 = 10334 \text{ k}^{\text{m}}.$$

(2.) The part yielded by expansion. This equals

$$31756 - 10334 = 21442 \text{ k}^{\text{m}}.$$

After, as well as before, expansion, the air is found at a temperature of 20°, since we have assumed that it follows Mariotte's law. No heat, therefore, is dissipated during expansion: but, as we secure at the same time 21,422 kilogrammetres of work, and since there is no production of work without a corresponding dissipation of heat, it is necessary to introduce into the air working expansively

$\dfrac{21442}{424} = 50{\cdot}52$ thermal units, a quantity equal to that which we found above for compression.

The quantity of heat which is to be abstracted from the air which is compressed, in order that the change of tension may follow Mariotte's law, is therefore precisely equal to that which must be supplied to it during expansion, if the latter shall follow the same law.

If we succeed, by the use of water-spray, in heating the expanding air sufficiently to bring its temperature again to that of the atmosphere, the water at its exit from the cylinder can evidently not have a temperature lower than that of the atmosphere. Again, there can be no heating of the air, if there be no surrender of heat by the water; and this surrender is possible only if the temperature of the water at its entrance is higher than at its exit. Consequently, to keep the temperature of the expanding air from falling below that of the atmosphere, it is necessary that it have at its disposal water whose temperature exceeds that of the surrounding air.

Now as the water met with in mines is mostly of a temperature equal to, or lower than, that of the air of the galleries, we cannot consider it possible, in practice, to cause the compressed air to expand according to Mariotte's law, but we can approach it very nearly, as we are about to show.

Suppose the atmosphere of the mine to be at 20° C., and the water we find there to be at 18° C. If we assume that the temperature of the air, during expansion, is to remain between that of melting ice and that of the atmosphere—as, for example, at 8·8°—every kilogramme of water will deliver to the air $18 - 8{\cdot}8 = 9{\cdot}20$ thermal units.

Expansion will proceed, according to Mariotte's law, only from the moment when the temperature shall have descended to 8·8°, which corresponds to a tension of seven atmospheres. The work realized in this case will be 20,801 kilogrammetres, and the quantity of heat to be introduced into the cylinder would amount to $\frac{20801}{424} = 49{\cdot}05$ thermal units, had not the air been cooled from 20° to 8·8°, thus losing $1{\cdot}199 \times 0{\cdot}168\ (20 - 8{\cdot}8°) = 2{\cdot}26$ thermal units. The heat to be expended is, therefore, $49{\cdot}05 - 2{\cdot}26 = 46{\cdot}79$ thermal units; and the water, at 18°, to be injected into the cylinder amounts to $\frac{46{\cdot}79}{9{\cdot}20} = 5{\cdot}086$ kg.

After having made our calculations for a tension of five atmospheres, similar to those which we have just given, we prepared the

following table, in order to compare its results with those which we obtained for eight atmospheres of tension:

	Tensions.	
	8 Atmos.	5 Atmos.
A cubic metre of air, taken from the atmosphere, requires, in order to be compressed and introduced into the reservoir, the heat of compression not to exceed 39°, atmospheric pressure having been subtracted, . . .	21711 k^m	17538 k^m
Number of thermal units to be absorbed, ...	49·73 calor's.	37·53 calor's.
Quantity of water, at 15°, to be injected into the compressor, . . .	2·062 k^g	1·564 k^g
The same cubic metre of air, after having been compressed and returned at 20° C. in the reservoir, may yield, if the temperature does not descend below 8·80° (the work necessary to overcome the atmospheric pressure having been deducted), ...	20801 k^m	16231 k^m
Number of thermal units to be introduced to the air during expansion, .	46·79	36·02
Quantity of water, at 18°, to be injected into the cylinder, . . .	5·086 k^g	3·915 k^g
If we assume that 30 per cent. of the power of which we have to dispose is lost on passive resistances and dead spaces, there remain, as utilizable work, ...	14561 k^m	11362 k^m
Ratio of utilizable work to that spent in compression, or the useful effect, .	0·641	0·647
Utilizable work produced in a second, corresponds to	194 h. p.	151 h. p.
Consumption of water by expansion, per 75 k^m, or per useful horse-power, .	0·026 k^g	0·026 k^g

As compared with the useful work, the amount of water necessary to heat the air during expansion is therefore not greater for 8 atmospheres of initial tension than for 5. The ratio of the work utilizable to that expended in compression is also supposed to be the same in both cases. These points are very important in a practical point of view; for, if it be indifferent, on the score both of water-supply and useful effect, whether we compress to 8 or to 5 atmospheres, it is not so when we take into account the first cost of the compressor, the

pipes and the machines using the air in the mines. In fact, in a given pipe the resistance which the air encounters in its motion is proportional to the square of the velocity and consequently to the square of the volume which circulates through it in a unit of time, whatever be the tension. Now, one cubic metre of atmospheric air, when compressed to eight atmospheres, occupies a volume equal to $\frac{1000}{8} = 0{\cdot}125$ cubic metre, and can deliver in the mine 14,561 kilogrammetres of useful work, an expenditure per metric horse-power of $\frac{0{\cdot}125}{194} = 0{\cdot}000644$ cubic metre.

But if compression be carried to five atmospheres the volume occupied by the air is 0·200 cubic metre; the useful work 11,362 kilogrammetres, and the volume of compressed air corresponding to a horse-power, $\frac{0{\cdot}200}{151} = 0{\cdot}001324$ cubic metre.

If we represent by R and R' the resistances which compressed air at 8 and 5 atmospheres respectively would encounter in a pipe, we have the following proportion:

$$R : \overline{0{\cdot}000644}^2 :: R' : \overline{0{\cdot}001324}^2,$$

whence
$$R = \frac{(\overline{0{\cdot}000644}^2)\, R'}{\overline{0{\cdot}001324}^2} = 0{\cdot}251\, R';$$

and
$$R' = \frac{(\overline{0{\cdot}001324}^2)\, R}{\overline{0{\cdot}000644}^2} = 3{\cdot}983\, R.$$

That is: the frictional resistance of air in the same pipe will, for the same quantity of work delivered by it, be about four times greater for 5 atmospheres than for 8.

The use of air at a high tension, when the machine which utilizes it as a motive power is at a great depth below the level of the compressor, also presents an advantage due to the effort which the air in the vertical part of the pipe exerts in virtue of its weight. This effort which assists the motion of the air in the pipes may be calculated in the following manner:

Let $H =$ the difference of level between the compressor and the machine which utilizes the air; $1{\cdot}199 =$ the weight in kilogrammes of a cubic metre of air at atmospheric pressure and at a tempera-

ture of 20° C; 13,500 kilogrammes = the weight of a cubic metre of mercury; T = the tension of the compressed air in atmospheres; H' = the height of the column of mercury, by which the column of air can be equilibrated without taking into account the atmosphere.

We will have: $1{\cdot}199\, H\, T = 13500\, H'$,

whence $$H' = \frac{1{\cdot}199\, H\, T}{13500}.$$

If we make $H = 500$ metres, we find:

For a tension of 8 atm.,	. .	$H' = 0{\cdot}355$ metre,
" " " " 5 "	. .	$H' = 0{\cdot}222$ "
Difference,	. .	$0{\cdot}133$ metre.

That is to say, the resistance encountered by the air in the pipe will, for a tension of 8 atmospheres, be less by 133 millimetres of mercury, or by 0·175 atmosphere, than what it would be for 5 atmospheres.

The use of air at high pressure allows also the first cost of the compressor and the machine in which the air is utilized, to be greatly reduced. Indeed, let us suppose two machines at the bottom of a mine, doing quantities of work precisely equal; let them be supplied with air brought for the one at a tension of eight atmospheres, and for the other at a tension of 5, the air in both cases being restored to atmospheric pressure in the cylinders.

The volumes of these cylinders will be inversely proportional to the quantities of work obtainable from one cubic metre of air taken from the atmosphere, and compressed to 5 and 8 atmospheres respectively.

Let V = the volume displaced by the piston of the machine, working at the initial tension of 8 atmospheres.

Let V' = the volume displaced by the piston of the machine, working at 5 atmospheres.

We shall have: $V : V' :: 11362 : 14651$;

whence $$V = \frac{11362\, V'}{14651} = 0{\cdot}775\, V',$$

and $$V' = \frac{14651\, V}{11362} = 1{\cdot}290\, V,$$

that is the volumes of the two cylinders will be in the ratio of 1 : 1·290.

The same ratio will evidently exist between the volumes of the compressors.

§ 3. In order to determine the amount of this work, and properly to bring forward the importance, in a practical point of view, of the method of cooling and heating the air during compression and expansion, we have prepared the following table, in which we compare the results of four instalments of compressed air: two working at tensions of 8 and 5 atmospheres, respectively, without the employment of any device for cooling or heating, and consequently without expansion, and two at the same tensions, but with the application of these methods. In the four cases supposed, the useful work to be done in the mine, is equivalent to 40 horse-power, or 3000 kilogrammetres per second.

COMPARISON OF DIMENSIONS.

TENSIONS.	Without the application of cold or heat.		Cooling during compression and heating during expansion.	
	8 Atm.	5 Atm.	8 Atm.	5 Atm.
Utilizable work receivable in the mine, .	3000 k^m.	3000 k^m.	3000 k^m.	3000 k^m.
Losses on account of passive resistances and dead spaces, . . .	900 "	900 "	900 "	900 "
Actual work to be done by the air, . . .	3900 "	3900 "	3900 "	3900 "
The work obtainable from a cubic metre of air when first compressed and restored to the temperature of the surrounding atmosphere,	9042 "	8267 "	2080 "	16231 "
Volume of atmospheric air to be compressed per second, . . .	0·431 m^3.	0·484 m^3.	0·187 m^3.	0·240 m^3.
If the velocity of the compressor-piston be 1·20 m. per second, its diameter will be, . .	0·676 m.	0·717 m.	0·485 m.	0·505 m.
The work necessary to compress a cubic metre of air taken at atm. pressure, . . .	29518 k^m.	21209 k^m.	22711 k^m.	17538 k^m.
Work expended per second in the compression,	12722 "	10265 "	4247 "	4209 "
Practical power of the compressor, . .	196·6 h. p.	138·8 h. p.	56·6 h. p.	56·1 h. p.

If the mean velocity of the piston of the machine, which utilizes the air, be 1·5 m. per second, its diameter will be, .	0·214 m.	0·287 m.	0·398 m	0·452 m.
The volume of compressed air delivered by the pipe in a second, . .	m^3. 0·053870	m^3. 0·096800	m^3. 0·023375	m^3. 0·048000
The diameters of the pipes for which the resistances may be zero,	0·108 m.	0·152 m.	0·077 m.	0·115 m.

The diameters of the pipes as we have just given them, have been calculated by supposing the length of each to be 1500 metres and the machine using the air to be situated 500 metres below the level of the compressors. From the experiments made at Mount Cenis, the loss of pressure due to friction in the pipes was found to be directly as their lengths, directly as the square of the velocities and inversely as the square of the diameters. It has been found that the loss is 62 millimetres of mercury for a pipe whose diameter is 0·10 m., and whose length is 1000 metres, the air circulating through it with a velocity of 3 metres per second.

Let D be the diameter of the pipe, its length 1500 metres, M the volume of air, which is to pass per second:

$V =$ the velocity of the air $= \dfrac{M}{0{\cdot}785\, D^2}$; $R =$ the resistance opposed by friction to the motion of the air. It is measured in millimetres of mercury.

We shall have: $$R = \frac{62 \times 1500 \times 0{\cdot}10\, v^2}{1000 \times 3^2 \times D} = \frac{1{\cdot}0333\, v^2}{D}.$$

Replacing v by $\dfrac{M}{0{\cdot}785\, D^2}$, we find for the expression of the value of the diameter, $D = \sqrt[5]{\dfrac{1{\cdot}6768\ M^2}{R}}$.

Let us assume that R cannot exceed 335 millimetres of mercury in the two columns at eight atmospheres, nor 222 millimetres in the two at five atmospheres.

As we have seen above, these values represent the effort due to the weight of the air and is that which comes to its assistance in its motion. If we replace R by these values in the formula given above, the value of D will be such that there will be no resistance to the

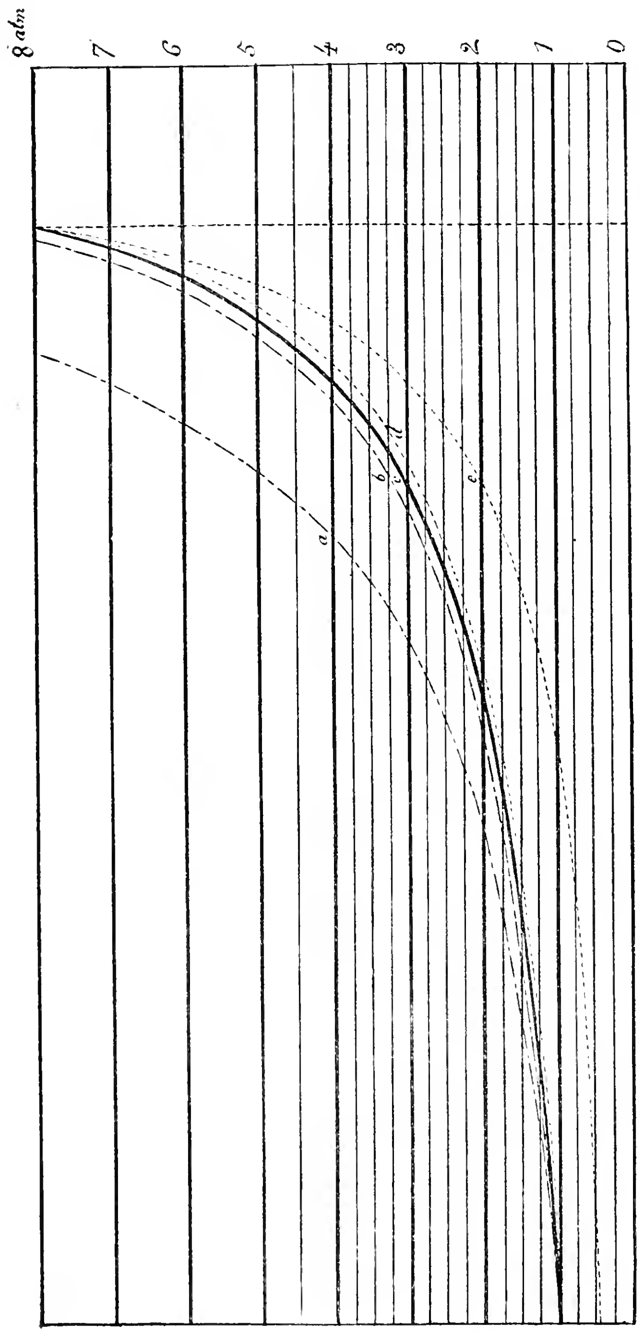

Fig. 2. A diagram indicating the variations of pressure in a cylinder 1 *metre long, where the air is carried to* 8 *atmospheres and then allowed to expand.*

a, Compression with increase of temperature of the air from + 20° to + 263·67°.
b, " temperature varying from + 20° to + 39°.
c, " at the constant temperature of + 20°. Mariotte's law.
d, Expansion of the air with temperature varying from + 20° to + 8·80°.
e, " with a decrease of temperature from + 20° to — 148·20°.

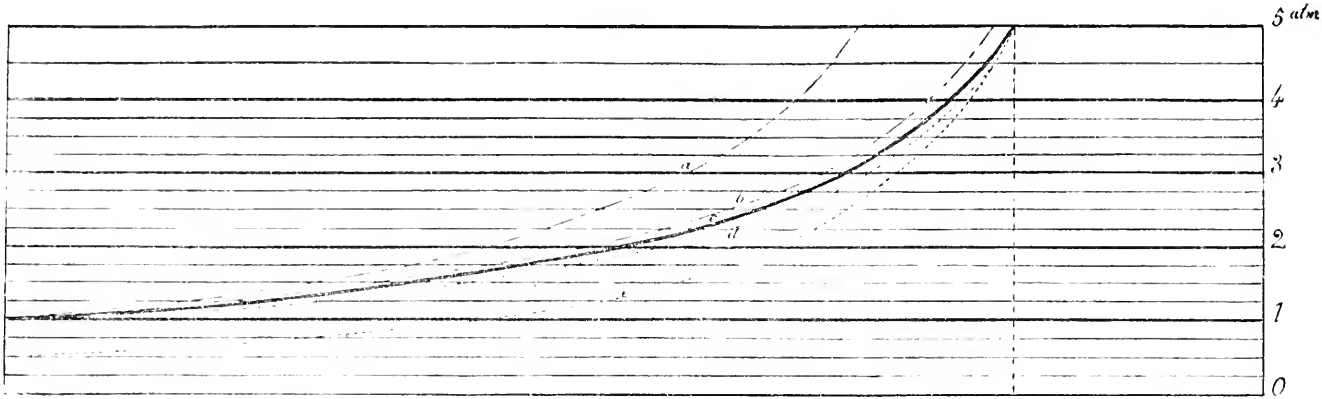

Fig. 3. A diagram indicating the variations of pressure in a cylinder 1 metre long, where the air is carried to 5 atmospheres and then allowed to expand.

a,	Compression with increase of temperature of air from	+ 20° to + 159·30°.
b,	" " temperature varying from	+ 20° to + 39°.
c,	" " a constant temperature of	+ 20°. Mariotte's law.
d,	Expansion of the air at temperature varying from	+ 20° to + 8·80°.
e,	" with decrease of temperature from	+ 20° to — 148·20°.

movement of the air, in the pipes. We thus find for the diameters of the pipes 0·108 metre, 0·152 m., 0·077 m., and 0·115 m.

It is sufficient to compare the figures of the preceding table to see how important would be the progress made in the use of compressed air in mining operations, were it possible to keep the temperature of the air from rising during compression much above that of the atmosphere, and from falling during expansion to the temperature of freezing water.

We think we have found the means for attaining this end, in the use of water-spray, which could be introduced into the cylinder of the compressor, and into that of the machine using the air in the mine. We have not indicated the practical details which permit the realization of our plan, but we appeal in behalf of this subject, to all constructing engineers. If they succeed, we may rest assured that the use of compressed air in mines will soon become general. We can likewise predict that the problem of mining at any depth will be solved.

N. B.—This paper had scarcely been completed when we noticed in a journal published at Mons, *Le Hainaut*, bearing date of February 19th, 1875, an article under the title of "Revue Scientifique," relative to the boring of the St. Gothard Tunnel. We there read the following passage, upon the importance of which, as bearing directly upon the subject in hand, it is needless to dwell:

"The compressor is that of Prof. Daniel Colladon, assistant to the contractor. The heat produced by compression is reduced by the circulation of cold water in the walls of the cylinder, in the interior of the piston and its rod; an injection of water-spray at the two extremities of the cylinder completes the cooling. The mine compressors furnish 15 cubic metres of air per minute in the tunnel."

We find in the *Revue Universelle des Mines* (Vol. xxxvi, No. 1), some details, due to M. Habets, regarding the compressor of M. Colladon. Compression to six atmospheres is effected at St. Gothard without exceeding a temperature of 35° C., and with a consumption of only 1 litre of injected water for every cubic metre of air taken.

The first part of our plan, *i. e.*, the use of water-spray to keep down the temperature during compression, is, therefore, not as new as we at first supposed. As to the second part, which consists in using the same means to keep the temperature of the air, during complete expansion, from falling to that of melting ice, we believe it has never been practiced, or even suggested, up to this time.

THE NATURAL SCIENCES IN COMMON SCHOOLS.

[Abstract of a paper read by Prof. JACOB ENNIS, at a Meeting of the Franklin Institute.]

Every day when the last half-hour of the schooltime arrives, the pupils should take their seats closely in front of the teacher's table. Then the teacher should perform some scientific experiment, or exhibit some object of natural history, and tell all that can well be told about it. That is, he, or she, should every day deliver a conversational lecture half-an-hour long, and practically illustrated by some exhibition in science. When taught in this way, the natural sciences are more easy to be learned than arithmetic or grammar. It is as easy to understand that oxygen and hydrogen unite to form water, as that two and two make four; and the delight to the child in seeing water composed in this way, is greater, beyond all comparison, than to see that two and two make four. What can be easier than to learn that the common salt which we daily eat is composed of a metal (sodium), and a beautiful greenish-yellow gas (chlorine). As all the words of a book are composed of only twenty-six letters, so every child can understand that all the various substances on our globe are composed of sixty-three simple elements. The great science of chemistry is nothing more than to have a knowledge of these sixty-three elements, and how they are united to form compounds, and what are the natures of these compounds. The first step for the learner is to see these simple elements, to handle them, to experiment with them, and to understand their chief characteristics. This lets the child at once into the great secrets of the universe, as clear as day, and he is delighted.

All the other physical sciences can be made as simple and easy as chemistry; and when all are harmoniously united, what a world of wonder do they open before the astonished view of the youthful mind. It is quite enough for the young student to learn the *general principles* of these sciences, copiously illustrated by facts. They are the most valuable parts of a science, for they give a bird's-eye view of an entire science, and the methods of working in that science. These general principles are also the most delightful portions. On this account it is that in an ordinary course of education, say until the child is 15 or 16 years old, all the natural sciences should be intro-

duced. Then the child imbibes and enjoys the very cream of them all. He is delighted, because he is every day seeing and hearing something new. What he learns with delight, he remembers long. Indelible ideas and impressions are then produced. He may very properly omit the *minutiæ* of the sciences, the difficult and the puzzlesome parts, parts which may be learned from books in maturer years; for it is a wonderful fact, which may well fill us all with amazement at the wide extent of creation, that all the sciences are so very extensive, that no scientific man is perfect in any one. No astronomer knows all the facts in astronomy, no chemist is familiar with all the facts in chemistry, no botanist knows all the plants, no zoologist knows all the animals. Therefore, the mouth of the objector is stopped. If a child is not to study the sciences because he cannot learn everything they contain, then no one should study them at all.

Delight the pupils during the last half-hour every day with the wonderful exhibitions and the wonderful truths of the sciences, and those pupils will make more rapid progress in all their present primary studies. Instead of being a hindrance to the other branches, the sciences must be a help. If the child's progress is now slow, it is not for want of time, but for want of interest in his school. Awaken an interest, and he will go forward. The natural sciences are the very things to arouse attention, to inspire life and animation. I do not wonder that, in general, children find their schooling process very irksome and distasteful. There is but little to relieve the confinement and restraint. Geography, for instance, is studied from the time a child is 8 until he is 16 years old; that is, during eight long and weary years. No wonder that during this long space of time, geography grows stale and insipid. The same may be said of grammar, and all the present primary studies. And yet the objectors to the sciences complain that the boys and girls, on leaving school, are still generally deficient in their primary studies. I am told that, on entering the Boys' High School or the Girls' Normal School, the new pupils are found so very deficient in arithmetic and grammar, as to require much additional time in those institutions to bring them up to the proper standard. And so things will continue as long as the present system lasts. It has been tried long enough and found wanting. But introduce the natural sciences, and all will be animation and encouragement. New life and new progress will

be infused into all the other studies. The enjoyment of the scientific exhibitions and the conversational lectures, is like their dessert after dinner. It is not only the most delightful, but the most profitable part of the exercises of the day, for the pupils learn more in that last half-hour than during any hour and a-half before. All this is not theory nor conjecture. It has been my daily observation during many years.

The proportion of female to the male teachers in our public schools, is as 30 to 1. Every year, hereafter, 250 young ladies are to graduate from the Girls' Normal School, with teachers' certificates. In that institution the ancient and the modern languages are not taught, and the mathematics are pursued only to a moderate extent; therefore, an abundance of time is left for the study of all the natural sciences, so that those new teachers may bring all these sciences, experimentally and practically, in our public schools.

It was a great benefit to Baltimore when the late Mr. Hopkins gave $3,500,000 to found a university in that city, but it would be a greater benefit to Philadelphia if all the natural sciences were taught, experimentally, every day in all our public schools.

The Maiche Battery.—The inventor states that when his platinized-carbon battery is charged with water acidulated with 10 per cent. of sulphuric acid, a zinc surface of 25 square centimetres is sufficient for the production of electric light. The electromotive force is, however, only about two-thirds as great as Bunsen's. By charging with bichromate of potash, he makes his battery the most intense of all, for the two forces are combined, and it possesses an electromotive force superior to that of the bichromate, while furnishing a double quantity of electricity. His battery has, therefore, the advantage of either being charged with simple acidulated water, or with the addition of the bichromate which makes it the most powerful known electro-generator.—*Les Mondes*, March 15. C.

Decomposition of Barium Dentoxide, at low Temperatures.—Gay-Lussac anticipated that in a vacuum, dentoxide of barium would be decomposed at a much lower temperature than at the ordinary atmospheric pressure. M. Boussingault finds that a complete decomposition is effected at a dull red heat.—*Acad. des Sciences*, March 19. C.

UNDERGROUND TELEGRAPHS IN FRANCE.

[From *Engineering*, London, May 4th, 1877.]

As might be assumed, the mileage of underground wires laid down in the city of Paris is very much below that over which London foot-passengers tread as they traverse the streets of our metropolis. Nevertheless Mr. Aylmer's paper on "Underground Telegraphs in France," recently read before the Society of Telegraph Engineers, possesses many features of interest, and some points which it may be worth noticing.

The earliest attempts made in France to establish underground telegraphs consisted of merely burying copper wires covered with india rubber. Then followed wires covered with gutta percha treated in a similar manner. In both cases the wires were simply laid in the bottom of the trench provided for their reception, and thus wholly destitute of protection, their speedy failure was, as happened, only to be expected. Towards 1852 a plan was tried of drawing the insulated wire into a lead pipe of as nearly as possible its own diameter. Failure again ensued, by reason of the infiltration of street gas at the joints in the lead pipe. Moreover, the percha covering of the wire frequently became so torn in the operation of drawing it into the pipe as to establish contact between the conductor and the lead coating. Some years later another method was tried. It had been observed that some naked wires which had been imbedded in asphalt some ten years previously, retained their insulation. A trench, some 5 ft. deep, was accordingly dug, a layer of fine sand was laid in it, and iron wires of No. 8 B. W. G. (chosen in preference to copper wire on account of its being less susceptible of variation from changes of temperature) stretched in the trench in sets of 4, 6, or 10, and in sections of 90 yards in length, being held at a uniform distance from each other by means of specially constructed guides which could be removed after the asphalt had been applied. A hot compound, composed of 60 parts of asphalt, 7 of bitumen, and 33 of fine washed gravel, was then poured into the trench so as to completely envelop the wires. For a few years the result was in every way satisfactory, but ultimately loss of insulation, and finally contacts, became frequent. Movements of the soil cracked the insulating compound,

which, moreover, lost its qualities and became soft where exposed to the action of escaped gases from the gas mains. The cost of this method was about 40*l.* per mile per wire.

In 1858 attempts were made to employ lead pipes. Five or more gutta percha covered wires, first covered singly with tarred hemp, and then when twisted up into a cable again wound round with tape, were drawn into a lead pipe, which was laid into a trench and covered up. Mechanical injury and bad joints in the leaden pipe soon caused its abandonment.

So far Mr. Aylmer merely relates France's early efforts in the direction of underground wires—all of which were attended, more or less, with failure. We now come to the system at present in use, and which may be regarded as successful, from the fact of its having already stood the test of twelve years' work. And here it may be well to note that the underground telegraphs in France, as carried out at the present date, come under two distinct and different conditions, viz., that in which the wires follow the route of, and are laid in, the street sewers of Paris, and that in which they are laid underground in trenches in the ordinary way.

Paris, as is generally known, possesses a very complete system of sewers. They are not what may be regarded as merely large drains, but are veritable subways, in any of which a man may freely move about. The main sewers are broad and lofty tunnels, with footways on either side—the sewage flowing at a low level in the centre. They are kept scrupulously clean, and frequent manholes, opening into the foot pavement above, give means of access, light and ventilation. As may be imagined, Parisian engineers have not been slow to recognize the advantages which such a system of subways presents for laying telegraph wires, pneumatic tubes, water and gas mains.

Whether the wires are to be laid along the sewage system or underground, up to a certain point they are subject to the same system of preparation. Gutta percha wires, such as are used in England, are made up into cables, protected by a serving of stout, tarred, hemp strand, which has again a covering of strong tape, also tarred. Before being tarred, both the hemp and the tape are steeped in a solution of sulphate of copper. Only the best Stockholm tar is used. Thus composed, the cable is fit for laying in pipes underground, but when required for use in a sewer, it is drawn into a lead pipe in size as nearly as possible that of the cable. Before being drawn into the

pipe, the cable is rubbed with talc to reduce friction. Finally the lead pipe is passed through a wooden die, which causes the lead tube to adapt itself to the cable within it. Lengths of about 100 yards are thus prepared and joined up before being placed in position. The tubing is usually ·05 of an inch thick, and the joints are made in the following manner: The core is first joined through, and this done, the wires are tightly wound round with a band of stout vulcanized rubber. Strong yarn is passed round this and tarred canvas over it, which is also bound with yarn. A piece of lead piping, previously slipped on, is now brought over the joint, and its ends pinched tightly round the cable tube. The whole is then finally wrapped with tarred canvas, well bound with galvanized iron wire. The result is said to be a very compact joint, formed without the intervention of heat. When all complete the cable is lifted into its place, usually specially prepared brackets, capable of holding two or more cables, fixed to the walls of the sewer.

The treatment of underground wires is somewhat similar, except in the make-up of the cable, to that pursued by our own telegraph engineers. The cables are drawn into pipes from 2 in. to 4 in. in diameter, in lengths of from 200 to 400 yards. Special and carefully devised apparatus is employed for drawing in the cable. There is, however, this difference between the French and our own system—slip pipes are used at specified distances in the place of what are known with us as "flush-boxes"—that is, boxes, the lids of which are laid level with the street pavement, by means of which access may be readily had to the wires within. The French system of slip pipes involves the opening of the street at the point where it is used, which in this sense, is disadvantageous.

The electrical condition of the Paris wires is spoken of as being higher, as a rule, than that required by the French Telegraph Administration, viz., 675 megohms per statute mile, at 20 degrees Centigrade.

Lines constructed upon these two principles have been in use over 12 years; none of them have broken down or shown signs of decay. Within the city of Paris there are 119 miles of underground line, of which 39 miles are laid in buried iron pipes, and 80 miles are in lead tubing laid in the sewers. The total length of wire is 2561 miles. In the chief provincial towns in France there are about 100 miles of similar lines at work.

CHICAGO PUMPING ENGINES.

The test of the pumping engines lately constructed for the West Side Pumping Station of the city of Chicago, Ill., by the Quintard Iron Works of New York, was commenced in the month of January last, but in consequence of the condition of the boilers, from the presence of scale and mud, extreme cold weather and injudicious firing, the engines failed in the required duty of 90,000,000 ft. lbs., although they discharged more than the required volume of water, of 30,000,000 U. S. gallons in 24 hours.

The Commissioners upon this occasion were: Moses Lane, of Chicago; Chas. H. Haswell, of New York; Henry Warrington, of Chicago; Chas. Hermany, of Louisville; and T. J. Whitman, of St. Louis.

The boilers having been cleaned, and more reliable means effected of measuring both the flow of the water delivered and the height to which it was raised, than upon the previous occasion, the test was renewed on the 18th of April, under the direction of Messrs. Lane, Haswell and Warrington, and continued for 48 hours with each engine, with the following results:

	ENGINES. No. 25.	No. 26.
Period of operation, .	48 hours.	48 hours.
Pressure of steam at boiler, . . .	61·77 lbs.	60·86 lbs.
Pressure of steam at engine, . . .	59·25 lbs.	60·25 lbs.
Point of cutting off, .	30 to 33 in.	30 to 33 in.
Revolutions, . .	11·177 per min.	10·63 per min.
Temp. of feed water, .	124° 4′.	131°.
" external air .	45° 9′.	60° 48′.
" engine room,	75°.	77° 94′.
" fire room, .	77°.	73°.
Coal consumed (Lackawanna broken lump),	42,400 lbs.	43,028 lbs.
Av. height of water in standing pipe. .	155·83 ft.	159·11 ft.
Av. height of water as indicated by pressure-gauge at delivery, .	157·06 ft.	159·34 ft.
Feed water per hour, .	9779·5 lbs.	10059·4 lbs.
Width of weir, . .	7·94 ft.	7·94 ft.
Av. height of weir, .	·9787 ft.	·9543 ft.
Volume of leak in weir-box or flume, .	5768 cu. ft.	5768 cu. ft.

The volume of water discharged, computed by Francis's formula, and the duty developed for each engine, were as follows:

VOLUME.

$Q = 3{\cdot}33 \times {\cdot}9787^{\frac{3}{2}} (7{\cdot}94 - \overline{{\cdot}2 \times {\cdot}9787}) \times 172800 = 4314617{\cdot}28$ cu. ft.

Leakage of weir-box and gate, ...	5768· " "
	4320385·28 cu. ft.

In 48 hours = 16159363 gallons in 24 hours.

DUTY.

Hence, $\dfrac{4320385{\cdot}28 \times 62{\cdot}4 \times 155{\cdot}83}{\dfrac{42400}{100}} = 99066718{\cdot}27$ lbs. of water raised 1 ft. in height, with 100 lbs. of coal.

The engines are vertical compound, with over-head beam.

PRINCIPAL DIMENSIONS.

High-pressure cylinder, diameter 48 in.
Stroke of piston, 6 ft.
Low-pressure cylinder, diameter 76 in.
Stroke of piston, 10 ft.
Pump, 51 in.
Stroke of piston, 10 ft.
Fly-wheels, each 32 ft. in diameter and 60 tons in weight.
Beam, 36 ft. in length and 7 ft. in depth.
Boilers, 4 cylindrical, fire tubular return.
Diameter of shell, 6 ft. 6 in.
Length, 16 ft.,
Tubes, 100 of 4 in. in diameter and 16 ft. in length.
Drum, 3 ft. 6 in. diameter and 8 ft. in height.
Grate surface, 116 sq. ft.
Average consumption of coal per hour, 890 lbs.
Average evaporation per pound of coal, 11·12 lbs.

Fire-proof Paper.—Asbestos is found in large quantities in the valley of Aosta, in the Italian Alps. A priest of Arezzo, named Victoria del Corana, has experimented with it in the paper mills of Tivoli, and is now making a fire-proof fabric at a cost of four francs per kilogramme. The most useful application which has yet been made of the paper, is for the decorations of theatres.—*Papier-Zeitung*, April 19. C.

ON THE TEMPERATURE OF COMBUSTION.

By M. Berthollet.

[Translated from the *Comptes Rendus* of March 5th, 1877, for the Journal of the Franklin Institute, by Chief Engineer Isherwood, U. S. Navy.]

1st. The temperature of combustion of a gaseous mixture is, as all know, the excess of temperature which will be acquired by the gaseous products of combustion if they preserve the totality of the heat disengaged in the reaction. Q being that quantity of heat and C the specific heat in weight of the products, we have $t = \frac{Q}{C}$, a formula which applies equally when the two gases burn in equivalent proportions, and when they are mixed with incombustible gases. In most cases, as M. H. Sainte-Claire Deville has shown, only a portion of the combustible gases enter into reaction; another portion remains in presence of a corresponding quantity of oxygen, because the temperature developed is high enough to determine the partial decomposition of the combination (dissociation). Let k be that combined fraction and C_1 the mean specific heat (between zero and t) of the system, such as exists at the moment of the combustion, we shall have, in general,

$$t = k\frac{Q}{C_1}. \quad . \quad . \quad . \quad (1)$$

Q is a constant which depends solely on the initial temperature, which is here supposed to be zero; but t, k and C_1 are three variables connected by equation (1).

2d. We can find a second relation between these three variables by adopting the experiments of M. Bunsen (*Ann. Pogg.*, 1867). The idea of this illustrious physicist was to burn the combustible mixture at constant volume and to measure the pressure P developed at the moment of combustion. Thus, calling g the theoretical condensation, that is the proportion of the volume of the gases produced in a total reaction after cooling, to the volume of the primitive gases, we have the relation:

$$P = P_0(1 - k + kg)(1 + a\,t). \quad . \quad (2)$$

Let a still be the mean specific heat at constant volume of the component gases, and b that of the composite gas, we have,

$$C_1 = (1 - k)\,a + k\,b, \quad . \quad . \quad . \quad (3)$$

$$t = \frac{k\,Q}{(1 - k)\,a + k\,b}, \quad . \quad . \quad (4)$$

$$\frac{P}{P_0} = (1 - k + k\,g)\left[1 + \frac{a\,k\,Q}{(1 - k)\,a + k\,b}\right]. \quad . \quad (5)$$

As we have for the three unknowns t, k, and C_1 connected by equation (1), substituted five connected by the three equations (3), (4), and (5), the problem remains indeterminate.

3d. M. Bunsen endeavored to resolve it by two hypotheses, namely, that the specific heat a of the component gases, and that of their products b, are constant quantities independent of the temperature and pressure. Thence k and t will be given by two equations of the second degree. The following table contains a summary of the results of M. Bunsen, whose permission to transcribe them has been obtained:

	Combustible mixture in volumes.		$\frac{P}{P_0}$ (Experiment.)	k (Calculated.)	t (Calculated.)
I	$\frac{2}{3}\,C\,O + \frac{1}{3}\,O$		10·78	0·351	3172°
II	ditto		10·19	0·319	2893
III	$\frac{2}{3}\,C\,O + \frac{1}{3}\,O$	$+0{\cdot}1079\ O$	9·05	0·314	2558
IV	ditto	$+0{\cdot}6857\ C\,O$	8·89	0·460	2471
V	ditto	$+0{\cdot}8554\ O$	8·44	0·478	2325
VI	ditto	$+1{\cdot}0861\ O$	7·86	0·490	2117
VII	ditto	$+1{\cdot}2563\ Az.$ (air)	7·73	0·515	2084
VIII	ditto	ditto	7·35	0·470	1909
IX	ditto	$+1{\cdot}7145\ O$	6·67	0·520	1726
X	ditto	$+2{\cdot}1559\ O$	5·83	0·512	1460
XI	ditto	$+3{\cdot}1629\ C\,O$	4·79	0·527	1146
XII	$\frac{2}{3}\,H + \frac{1}{3}\,O$		9·97	0·338	2854
XIII	ditto		9·75	0·336	2833
XIV	$\frac{2}{3}\,H + \frac{1}{3}\,O + 1{\cdot}2599\ Az.$ (air)		7·49	0·547	2024

According to these figures k, or the fraction actually combined, would increase from 0·31 to 0·53 in measure as the presence of a larger proportion of inert gas lowered more and more the temperature of the combustion; and the variation would have its maximum in the neighborhood of 2500 degrees. The discrepancy of one experiment with another amounts to 6 per centum on the measured

pressure, corresponding to a difference of one-tenth on the combined fraction and on the temperature; nevertheless M. Bunsen believed himself entitled to conclude that k remained invariable and equal to one-third between 3200 and 2500 degrees, temperatures towards which half of the explosive gas rose suddenly to preserve anew a constant value until near 1150 and lower. There is no utility in discussing this question in a more profound manner, because the fundamental hypothesis of the constancy of the specific heat of the carbonic acid is erroneous.

4th. It is only for the simple gases near the perfect state, and for carbonic oxide formed comparably of gases without condensation, that the experiments of Regnault and of Wiedemann authorize the admission of the constancy of the specific heat under constant pressure between zero and 200 degrees. No other experiments have been made on the specific heats of gases under constant volume at different temperatures. Should we admit as a hypothesis which each may value as he chooses, that these conclusions are applicable to chlorohydric gas, the only compound formed without condensation and of which the formation can be determined by direct combustion, the specific heat of this gas being likewise reputed equal to that of its elements,[1] then, the equations of the first degree,

$$t = k\frac{Q}{C}, \text{ and } P = P_0\left(1 + a\,k\frac{Q}{C}\right),$$

permit the calculation of t and k, that is to say the dissociation, by the analogous experiments of M. Bunsen.

5th. But none of these hypotheses, and consequently none of these calculations, are authorized by experiment for the gases formed with condensation, such as carbonic acid; in fact, the specific heat of such gases vary, and very rapidly, with the temperature. In connecting the specific heat under constant pressure with the molecular weight (which occupies 22·32 $l.$ at zero and 0·76 metre), we find for the mean values of that quantity between zero and 200 degrees:

For C^2O^4	$= 44$ gr.	$: C = 8{\cdot}41 + 0{\cdot}0053\,t.$	(Mean of Regnault and Wiedemann).
" Az^2O^2	$= 44$ "	$: C = 8{\cdot}96 + 0{\cdot}0028\,t.$	Ditto.
" C^2S^4 gas	$= 76$ "	$: C = 10{\cdot}62 + 0{\cdot}007\,t.$	Regnault.
" AzH^3	$= 17$ "	$: C = 8{\cdot}51 + 0{\cdot}00265\,t.$	Wiedemann.
" C^4H^4	$= 28$ "	$: C = 9.42 + 0{\cdot}0115\,t.$	Ditto.

[1] We know this last supposition to be not quite true, chlorine having a specific heat a little above that of the other simple gases under the same condition.

The condensation is $\frac{2}{3}$ for the first three gases; and $\frac{2}{4}$ and $\frac{2}{6}$ for the two others. It cannot be doubted that vapor of water would offer analogous variations.

The specific heats at constant volume have not been determined for different temperatures, but we know that their approximate value can be obtained for the gases which follow the laws of Mariotte and Gay-Lussac by considering the difference of the two specific heats as equivalent to the exterior work of dilatation, that is to say, as represented by 1·93. We should thence have the mean value:

$$\text{For } C^2\,O^4,\ C' = 6{\cdot}48 + 0{\cdot}0053\,t.$$

But it is more than doubtful if that value is applicable under pressures approaching 10 atmospheres.

6th. Let us calculate the combustion temperature of carbonic oxide with oxygen taken in equivalent volumes. According to this new data, and admitting $Q = 69000$, we would have

$t = \dfrac{69000}{8{\cdot}41 + 0{\cdot}0053\,t} = 2900°$ about, at constant pressure; and $t = 3060°$ about, at constant volume; temperatures greatly lower than the 7200° and 8300° to which we are led by the hypothesis of constant specific heats. According to the above empirical formula, $C = 54{\cdot}3$ between zero and 3000°, which is a little more than double the value of the specific heat of the elements supposed to be gaseous. This, however, according to analogies, is not at all impossible; indeed, it exists for the chlorides of phosphorus and of gaseous arsenic. At constant volume calculation gives $C = 22{\cdot}4$.

We must hasten to add that the empirical formula representing the specific heat of the carbonic gas only between zero and 200°, could be extended to 3000° as merely a hypothesis to render evident the erroneousness of old valuations. We can also show in other ways that the values deduced are too great for application to the totality of the combustible gas: in fact there results from it a pressure about one-fifth less than the figures found by M. Bunsen; but the admission of a partial dissociation is sufficient to render the pressures and temperatures compatible with the specific heat derived from the formula.

7th. Nevertheless, the measures of M. Bunsen remain very valuable, accepting them as exact, because they enable a calculation to be made of the two limits between which the temperature of combustion is necessarily comprised, and that without any hypothesis as

regards specific heat; nothing more is required for the calculation than an admission of the generality of the laws of Mariotte and Gay-Lussac. From equation (2) we draw in fact:

$$t = \left(\frac{P}{P_0}\,\frac{1}{1 - k + k\,g} - 1\right) 273. \qquad . \qquad (6)$$

It is clear that the combined fraction at the moment of explosion, is comprised between zero and 1 for a mixture formed in equivalent proportions; and between zero and m for a mixture containing $1 - m$ volumes of inert gas; whence in replacing k successively by zero and 1, or by zero and m, we shall obtain the two limits sought. These limits will be found in following table:

			$\frac{P}{P_0}$	t_1	t_2
I	$\frac{2}{3}\,CO + \frac{1}{3}\,O$		10·78	4140°	2612
II	ditto		10·19	3900	2537
III	ditto	$+ 0·1079\,O$	9·05	3066	2198
IV	ditto	$+ 0·6857\,O$	8·89	2760	2154
V	ditto	$+ 0·8554\,O$	8·44	2537	2031
VI	ditto	$+ 1·0861\,O$	7·86	2280	1875
VII	ditto	$+ 1·2563\,Az.$	7·73	2203	1838
VIII	ditto	ditto	7·35	2083	1734
IX	ditto	$+ 1·7145\,O$	6·67	1875	1548
X	ditto	$+ 2·1559\,O$	5·83	1505	1319
XI	ditto	$+ 3·1629\,O$	4·79	1150	1034
XII	$\frac{2}{3}\,H + \frac{1}{3}\,O$		9·97	3809	2449
XIII	ditto		9·75	3718	2389
XIV	ditto	$+ 1·2599\,Az.$	7·49	2126	1715

The combustion temperature of carbonic oxide with oxygen, at constant volume, is there comprised between 4000° and 2600°; and, with air, between 2200° and 1750°, limits already closely restricted. That of hydrogen with oxygen between 3800° and 2400°; and, with air, between 2100° and 1700°.

These last numbers appear rather small when compared with the melting point of platinum, estimated at 2000°, but in this estimation the specific heat of platinum is supposed constant, while, in fact, it varies with the temperature. If the laws of variation deduced from the measures of Dulong be adopted, platinum should melt at about 1400°; the true temperature is probably intermediate, but it is a disputed point: beyond the limits measured by the air thermometer no temperature is known with certainty.

We would remark that, starting from the mixtures which contain their volume or more of inert gas, the difference between the temperatures calculated by Bunsen and the limit which corresponds to a total combination, does not exceed one-tenth.[i] The difference falls to 45° and even to 4° for more diluted mixtures: such would be the interval between a total combination and a combination of one-half only; an interval too near the limits of experimental error to authorize any conclusion whatever, and *a fortiori* the admission of a simple law of discontinuous numerical relations.

But if these experiments give no other certain data relative to the degree, to the nature, or even to the existence of dissociation,[ii] they appear, notwithstanding, to establish the possibility of producing temperatures really approaching 3000°.

Curious Phenomenon of Heat.—M. J. Olivier reports the following experiment: A square bar of steel, about 15 millimetres thick, and 70 to 80 mm. long, is grasped firmly by the operator, one hand being placed at the centre of the bar and the other at one end. The free extremity is pressed strongly against a rapidly revolving emory wheel. In a few minutes the rubbed extremity becomes hot, the hand at the centre of the bar feels no heat, but the hand at the remote extremity becomes so hot that the operator is obliged to loosen it. C.

Coloring Canned Vegetables by Chlorophyle.—MM. A. Guillemare and F. Lecourt have experimented successfully with chlorophyle, as a substitute for the salts of copper in giving a green color to peas, beans, cucumbers, and other canned or pickled vegetables. The color thus obtained is said to be more natural than that which is given by copper, the vegetables are more wholesome, and the flavor is better on account of the absence of all astringent or metallic taste.—*Comptes Rendus*, April 9. C.

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[i] M. Bunsen admits $Q = 67300$ in place of 69000, but this change in the heat of combustion of carbonic oxide does not sensibly modify the results of the calculation.

[ii] Cyanogen burnt in air at constant volume forms an exception. In fact, it is easy to prove, admitting the pressure (11 atmospheres) observed by M. Bunsen, that the product is not composed exclusively of carbonic oxide, oxygen and azote, but that it necessarily contains carbonic acid, the temperature of combustion being comprised between 2700° and 2100°.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. ciii, page 417.]

Since 1870 the muffle-furnaces formerly employed at Stolberg have been combined with a system of plates according to the design of Hasenclever and Helbig. The system has subsequently experienced important modifications, retaining the principle for inclined plates, until a kiln for blende has been developed which has now for some years been found suitable to be retained in an unmodified form.[ii] The products of combustion, which play round the muffle, heat from below an inclined plane formed of plates and about 8 metres in length. On this inclined plane the ore slides down to a roller fixed at the lower end, and as this revolves is delivered first into the muffle, whence it is drawn down by manual labor into the lower hearth, where it is roasted until fit to be smelted for zinc. The gases escaping from the muffle, still poor in sulphurous acid, sweep over the inclined plane, become richer, and effect a preliminary roasting of the blende. Since finely granular bodies if thrown on a heap form a surface with an approximately constant angle of 33°, as the ore slides down the plane which has an inclination of 43° there would be formed at the bottom a heap of more than 1·5 metres in depth, a perfect roasting of the interior of which would be impracticable. To prevent the stratum of ore from becoming too thick, partitions are arranged, which descend to the distance of a few centimetres from the slope. In this manner a thin stratum of ore is maintained over the whole surface. Furnaces of this construction are at work at Oberhausen and Stolberg, and are in course of construction at Lethmathe, near Iserlohn, and Rosdzin, in Silesia. The consumption of fuel is the same as in the roasting kilns common at zinc works, 28 per cent. of coal to 100 raw blende; the cost of labor is 1·6 of a shilling per 100 kilos. blende.

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i "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

ii Hasenclever and Helbig, *Zeitschr. des Vereins Deutscher Ingenieure*, 1872, 705.

In Freiberg a black blende, containing iron pyrites in considerable amount, is used for the manufacture of sulphuric acid, the broken ore being submitted to a preparatory roasting in large kilns. The burnt residue is then ground and receives its final roasting in a reverberatory.

Formation of Sulphuric Acid in the Lead Chambers.—Recently, as well as in earlier years, proposals have been made to substitute some other apparatus for the chambers. Verstraet[i] employs for this purpose columns formed of earthen vessels. But his method, like earlier suggestions for preparing sulphuric acid on any other than the traditional principle, has not become of practical importance.

The chemical process during the formation of sulphuric acid in the chambers, and the reactions involved, have been latterly further explained.

Reich[ii] introduced a method of determining the sulphurous acid in the gases from the kilns and furnaces, which has met with an extensive application. He uses a solution of iodine in potassic iodide of known strength, to which a little starch has been added. By aspiration the gas is drawn through the blue liquid till decoloration is effected. If the volume of the aspired gases has been measured the percentage of sulphurous acid is known. This method of examination has the great advantage that it can be accurately executed by a common laborer (?), the solution of iodine merely being prepared in the laboratory.

The composition of kiln gases theoretically the most advantageous was first calculated by Gerstenhöfer, and was communicated to several chemical works as early as 1866. The same calculation, with a slight difference, was subsequently produced by Schwarzenberg.[iii] According to his assumption, when the chambers are working well the gaseous mixture leaving them should still contain 5 per cent. (by volume) of oxygen. Hence the normal composition of the gases entering, when sulphur is employed, must be:—

Sulphurous acid (by volume), . .	11·23
Oxygen, ...	9·77
Nitrogen, ...	79·00

[i] Verstraet, *Dingl. Pol. Journ.*, clxxix, 63. *Wagner Jahresber.*, 1865, 226.

[ii] Reich, *Berg und Huttenm. Zeitung*, 1858.

[iii] Schwarzenberg, "Bolley's Handbook der Techologie," ii, 355.

and when pyrites are in use, and the gases at their exit contain 6·4 per cent of oxygen—

Sulphurous acid,	8·59
Oxygen,	9·87
Nitrogen,	81·54

Since, for every 1000 grms. of sulphur used in the form of bisulphide of iron 8144·9 litres of gas (calculated at 0° temperature and at a pressure of 750 m. m. of mercury) enter the chambers, and for the same weight burnt in the free condition only 6199 litres, a given quantity of sulphur burnt as bisulphide of iron, yields—

$$\frac{8144{\cdot}9}{6199} = 1{\cdot}314$$

times as much gas as if it had been burnt in the free condition.

The number given above represents the proportion of the bulk of the lead chambers, which, for an equal production of sulphuric acid, is necessarily larger for roasting pyrites than when free sulphur is burnt. Gerstenhöfer, for the escaping gases both in roasting pyrites and in burning sulphur, employs a normal amount of 6 per cent. by volume of oxygen. Hence the most advantageous composition of the gases on entering, theoretically speaking, in case of sulphur is:—

Sulphurous acid,	10·65	by volume,
Oxygen,	10·35	"
Nitrogen,	79·00	"

For pyrites:—

Sulphurous acid,	8·80	"
Oxygen,	9·60	"
Nitrogen,	81·60	"

The statements as to the proportion of oxygen in the gases leaving the chamber, vary widely. According to R. Wagner[1] the escaping gases do not contain more than 2 to 3 per cent. of oxygen. Scheurer-Kestner, in a private communication to A. W. Hofmann, mentions that the gases escaping from the chambers contain 6 per cent. of oxygen, independent of the oxygen present in the form of nitrous acids. The varying statements may be due to the circumstance that

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[1] R. Wagner, *Chem. Techn.*, 9 edit., 1873, ii, 235.

some manufacturers use Gay-Lussac's column for absorbing the nitrous acid, whilst others work without it.

For the determination of the oxygen various apparatuses have been latterly introduced, especially arranged to permit of accurate tests being executed by a common workman.

Winkler has justly pointed out[i] the great technical value of gas analyses, and has described an apparatus which he has designed for the purpose.

Max Liebig[ii] has also accurately described another very serviceable apparatus for the same object.

Particularly interesting, both theoretically and practically, are the researches of R. Weber, of Berlin, on the theory of the manufacture of sulphuric acid. His first publication on this subject bears the date 1862. He[iii] analyzed the so-called "chamber-crystals," and assigned to them the formula, $HOSO_3+NO_3SO_3$, or, according to the present notation, $HSO_4+N_2O_3SO_3$. The accuracy of this composition has been since confirmed by other chemists.[iv]

In subsequent memoirs Weber[v] enlarges on the chemical process in the chambers; he points to the action of the nitrous acid, and assumes various reactions, according to the greater or smaller quantity of steam.

Kolb[vi] expounds the different theories on the manufacture of sulphuric acid in historical succession, and holds that Peligot has given the best explanation of the process. The last mentioned chemist pointed out in 1844 that "chamber crystals" were never formed during successful working. He maintained that the sulphurous acid was oxidized to sulphuric acid by the nitric acid, and represented the process in the following series of equations:—

$$
\begin{aligned}
NO_5+SO_2+ag &= NO_4+SO_3+ag \\
2NO_4 \qquad +ag &= NO_3+NO_5+ag \\
3NO_3 \qquad +ag &= 2NO_2+NO_5+ag \\
NO_2+2O \qquad &= NO_4
\end{aligned}
$$

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[i] Winkler. *Journ. f. Prakt. Chemie*, vi, 301.

[ii] Max Liebig, *Dingl. Pol. Journ.*, ccvii, 37.

[iii] R. Weber, *Journ. f. Prakt. Chemie*, lxxxv, 423.

[iv] Rammelsberg, *Bul. Chem. Ges.*, 1872, 310.

[v] Weber, *Pogg. Ann.*, cxxvii, 543, and cxxx, 329.

[vi] Kolb in his work cited in Jour. Frank. Inst., ciii, 271.

Transposed into the present notation these formulæ appear as—

$$\begin{aligned} N_2O_5+SO_2+H_2O &= N_2O_4+H_2SO_4 \\ 2N_2O_4+\quad H_2O &= N_2O_3+2(HNO_3) \\ 3N_2O_3+\quad H_2O &= 4NO+2(HNO_3) \\ 2NO+\quad 2O &= N_2O_4 \end{aligned}$$

Winkler[i] assumes that the process of sulphuric acid making depends essentially upon the reaction between sulphurous acid and hyponitric acid in presence of steam. According to his view there is formed a compound of sulphuric acid and nitrous acid, which sinks to the bottom in the form of a white mist, often observed; comes then in contact with the hot dilute chamber acid, and is dissolved therein, when nitrous acid is liberated and oxidizes a fresh dose of sulphurous acid, and is thereby converted into nitric oxide. This, in turn, seizing the free oxygen present is re-converted into hyponitric acid and commences its circulation anew.

Hasenclever, in his treatise on roasting furnaces,[ii] assumes that the reaction takes place in such a manner that sulphurous acid and nitrous acid in presence of steam form sulphuric acid and nitric oxide, which latter is then re-converted into nitrous acid by the air, thus rendering the process continuous.

Fr. Bode[iii] maintains that this view of Hasenclever transgresses the logical laws of thought, though, since, according to his formulæ, the decomposition and re-formation of nitrous acid must go on simultaneously under the same conditions, and that it is, moreover, contradicted by the view of Winkler, and by known chemical laws. Here we must remark, however, that, according to Bode's view, every theory of the formation of sulphuric acid must offend against the logical laws of thought, whether we consider, with Berzelius, that it is nitrous acid, with Winkler that it is hyponitrous acid, or with Peligot that it is nitric acid, which hands over oxygen to the sulphurous acid.

It is incontestable that nitric oxide gas is repeatedly oxidized and reduced in the chambers, and, though we must certainly assume that decomposition and recomposition go on simultaneously, it does not by any means follow that they must take place under identical condi-

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[i] Winkler in his work cited in Jour. Frank. Inst., ciii, 271.

[ii] Hasenclever, *Zeitschr. d. Ver. Deutsch. Ing.*, 1870, 706.

[iii] Fr. Bode, "Beiträge zur Theorie und Praxis der Schwefelsaure," Berlin, 1872.

tions. Molecules of steam, oxygen, nitrous acid, sulphurous acid, and sulphuric acid in an atmosphere of nitrogen traverse the chamber from end to end. According to Schwarzenberg's calculation of the percentage composition of the entering gases when working with pyrites, there are 53·5 volumes of oxygen to 46·5 volumes of sulphurous acid. At the very outset of the process, therefore, there are present in the gaseous mixture more molecules of oxygen than of sulphurous acid. In the further progress of the reaction the proportion of oxygen must increase, since in the formation of sulphuric acid only 1 volume of oxygen is removed from the mixture for every 2 volumes of sulphurous acid. As soon as a molecule of nitrous acid is reduced to nitric oxide, the reducing sulphurous acid disappears from its immediate vicinity, whence oxidation is at liberty to set in when the gaseous mixture enters the vacuum formed by the formation of sulphurous acid. If, then, during the further progress of the reaction, the molecules of nitrous acid and of sulphurous acid come again in contact, the formation of sulphuric acid and of nitric oxide is repeated, which latter is again transformed into nitrous acid. The oxides of nitrogen are therefore chiefly present in the chamber in the state of nitrous acid, less abundantly as nitric oxide. In fact, the faint yellowish color of the gases in the chambers, where it can be observed by means of skylights and side windows (*e. g.*, in the sulphuric acid works at Nienburg), supports this view.

Hasenclever assumed nitrous acid as the oxidizing agent for sulphurous acid, because, according to Weber's investigations, nitric oxide gas and oxygen in presence of hydrated sulphuric acid and even of an excess of oxygen, do not form hyponitric but nitrous acid, and because Winkler has detected sulphurous acid as predominant among the gases passing from the chambers into the Gay-Lussac tower.

So long, however, as among the various theories of the formation of sulphuric acid in the lead-chambers, successively proposed by Berzelius, Davy, de la Provostaye, Peligot, Weber, Winkler, etc., no one has been definitely established by exact experiments, we must content ourselves with the view given by Clément and Désormes[1] at the beginning of the century:—"Thus nitric acid is merely the instrument of the complete oxygenation of the sulphur.

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[1] Clément and Désormes, *Ann. Chim. Phys.*, lix, p. 329

It is its base, nitrous gas, which takes the oxygen from the atmosphere to offer it to the sulphurous acid in a suitable state."

Weber has also made interesting observations on the loss of nitre. He showed that losses of nitric acid might ensue not merely from the escape of nitric oxide and nitrous acid, but that in presence of an excess of water, nitrous acid is readily reduced by sulphurous acid to nitrous oxide. Fremy[i] also found that in the gases entering the chambers nitrous acid may be reduced to nitrous oxide, and even to free nitrogen if the sulphurous acid is too hot and too concentrated. Kuhlmann reported on this subject to the jury of the Vienna Exhibition, and writes, at length, to Dr. Hofmann as follows:[ii]

"In the manufacture of sulphuric acid the behavior of nitric oxide has been the subject of much investigation, but some points are still unexplained. The two following questions require an answer:

"1. In what circumstances is nitric oxide converted into nitrous oxide?

"2. Is such nitrous oxide the sole product which can be formed on the reduction of nitric oxide by sulphurous acid?

"In order to solve these questions it seemed advisable not to study the reactions in the chamber, but to submit the action of sulphurous acid upon nitric oxide in the absence of air to an accurate investigation. The two gases always act more or less upon each other, the sulphurous acid becoming oxidized to sulphuric acid by the oxygen of the nitric oxide. In order to ascertain how far this deoxidation of the nitric oxide can be carried, platinum sponge was introduced, which greatly facilitates the reaction between gaseous bodies. Nitric oxide may be in this manner reduced to nitrogen with formation of a corresponding quantity of sulphuric acid:

$$SO_2 + NO = SO_3 + N.$$

"Even without platinum sponge this reaction takes place, though incompletely. Even at ordinary temperatures some sulphuric acid is formed, and the more the heat rises the more energetic becomes the mutual reaction of the gases. It is possible that before the complete reduction of nitric oxide to nitrogen, nitrous oxide may be formed in

[i] Fremy, *Comptes Rendus*, lxx, 61.

[ii] Private communication.

the first place, but it is essential to note that the reduction does not come to a standstill with the formation of nitrous oxide. If sulphurous acid is brought in contact with nitric oxide at an elevated temperature, a complete reduction to nitrogen occurs. In these transformations the temperature plays an important part. In sulphuric acid works care must be taken that the gases do not act upon each other at too high a temperature, and the decomposition of nitre in the hot gases of the kilns must be absolutely condemned. If Glover towers are used for concentrating the chamber acid, they must be supplied with an acid as free as possible from nitrous acid; otherwise conditions are produced resembling those of the nitre decomposition just mentioned, where the reduction goes too far."

In fact the loss of nitre, with a complete absorption of the nitrous acid, in the Gay-Lussac tower, leads us to suspect that under certain circumstances reduction to nitrous oxide or nitrogen must take place. For the practical utilization of the experience collected in the laboratory, it will still be necessary to ascertain at what degree of condensation of the gases, and at what temperature the above-mentioned reduction ensues. Kuhlmann's observations may hold good in many cases, but they are not universally valid, since, according to the author's experience, some works consume a minimum of nitre, although the decomposition is conducted in the sulphur kilns and in the flues leading from the pyrites furnaces to the chambers.

(To be continued.)

Protection against Insects.—A soap, insoluble in water, may be prepared by mixing castile soap with a solution of sulphate of alumina, sulphate of iron, or sulphate of copper; copper making the mixture green, iron leather-colored, alumina colorless. It may be applied by melting, or by solution in petroleum or other volatile hydrocarbons. If the solution is not perfectly fluid, it should be warmed.—*Papier-Zeitung*, March 8. C.

Copper in Canned Peas.—M. Pasteur examined fourteen boxes of canned peas, bought at random in the principal quarters of Paris, and found that ten of them were colored by copper. Where there is no artificial coloring, the tint is always yellowish. There is no way of giving a green shade without adding a salt of copper. C.

WHAT I KNOW ABOUT LATE IMPROVEMENTS OF THE MICROSCOPE.

[Read before the Biological and Microscopical Section of the Academy of Natural Sciences, Philadelphia, June 4th, 1877.]

By JOSEPH ZENTMAYER.

A recent paper, by our fellow-member, Dr. J. G. Hunt, entitled: "Post-Centennial Microscopical Notes," read before this section, and published in the Cincinnati *Medical News*, has provoked considerable discussion, especially that part relating to my "American Centennial Microscope." As some of these important improvements have been claimed by other makers, I propose to bring the subject before you for investigation, with the endeavor to right the matter satisfactorily to all concerned.

In order to make the investigation a thorough one, it will be necessary for me to call your attention to the so-called Grand American Stand, made for this academy in October, 1859, and which now stands before you. The novel points of this stand, which I claimed at that time, were: 1st. The stage, with graduated revolving plate to serve as goniometer. Although very firm, it is only $\frac{3}{16}''$ thick, and is, even at the present date, the thinnest mechanical stage made. 2d. The graduated revolving base for measuring the angular apertures of objectives. 3d. The hanging of the mirror to a joint as near as possible to the plane of the stage.

Early in 1860, I made three stands (Nos. 13, 14 and 15) precisely like the Grand American, but somewhat lighter. No. 15 was made for a gentleman who was not in favor of mechanical stages, and who desired me to design for him a revolving stage, the object to be moved by hand, and it was for him that I constructed the first of my graduated stages, giving a complete revolution in the optical axis, *in a large ring, which is adjustable within another by three screws*, in order to have the axis of the stage coincident with the optical axis of the instrument, exactly the same as the one before you, which I made early in 1866. This stage has been for years extensively copied, in France and in England.

The hanging of the mirror by a joint as near as possible to the stage, I adopted long before I made the Grand American Stand. The first large stand I made has such a swinging mirror.

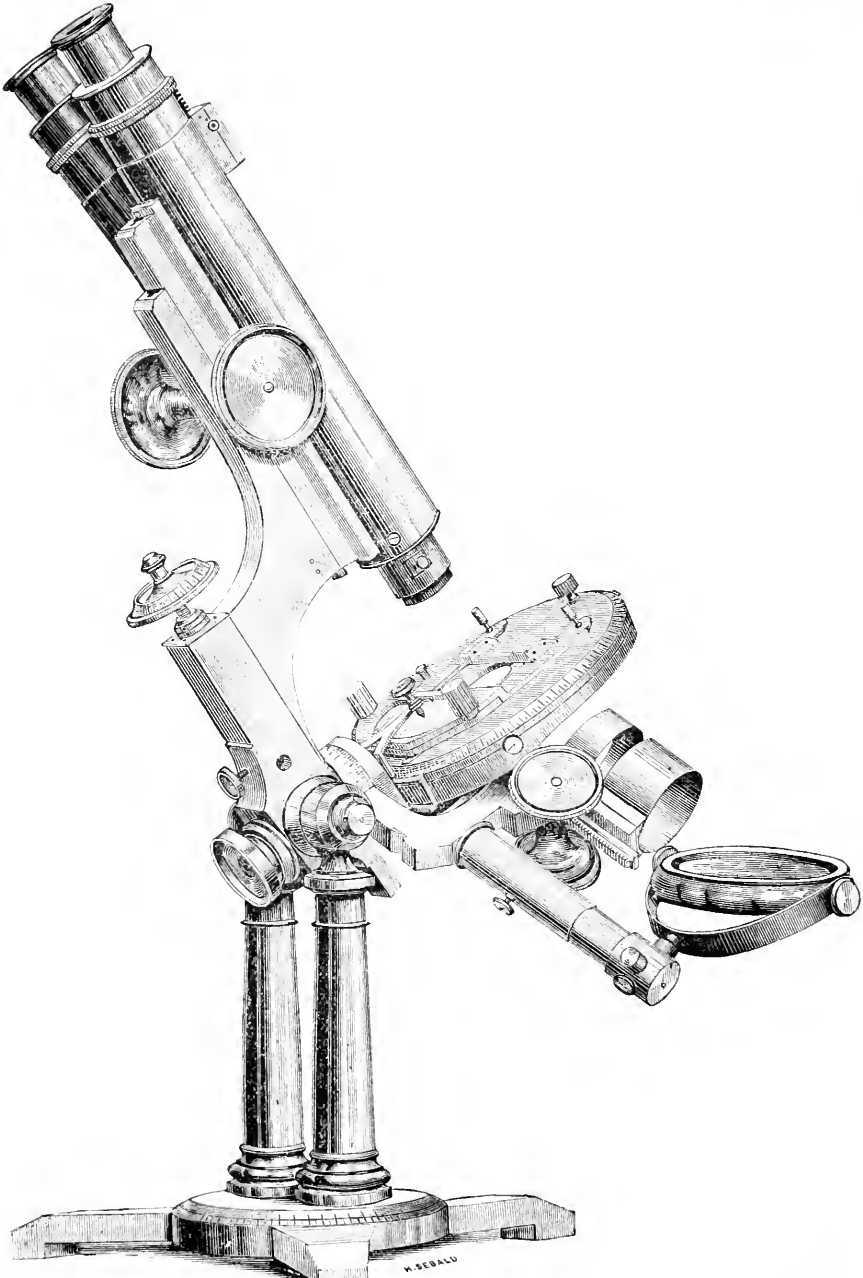
The microscope, to which I will now call your attention, is one which I made in 1864; the owner has kindly loaned it to me for this evening. The accompanying photograph was made in November, 1864. It is one of my army hospital stands, almost the same as made to-day, except that a sliding sub-stage is attached to the prismatic mirror bar, to receive the accessories. In the photograph you see an achromatic prism for oblique illumination (an apparatus which since then has also been brought out as new). Although handy as a mechanical contrivance, it is not of much importance; the mirror stem is only jointed near the stage, and has not the object under observation as its precise centre. If it had, it would be exactly the same as the swinging sub-stage and mirror of my new "Centennial Stand." About two years ago, in a conversation with Dr. J. G. Hunt, he pointed out the importance of having an arrangement for illuminating the object by an Achromatic Condenser in an oblique position. I explained to him how I would make a stand, in which this idea would be carried out in the most complete manner. The design and drawings were made soon after, but the instrument was not brought out, as I intended it for the Centennial Exhibition. Some of you have seen it before, and previous to bringing it to the exhibition, you recollect, it was shown at our meeting here, in April, 1876.

Messrs. Bausch & Lomb, of Rochester, N. Y., exhibited at the Centennial, a microscope stand with glass stage (a modification of mine); the mirror was hung to a swinging arm, and a diaphragm was attached to the mirror stem, quite similar to the instrument and photograph before you, made 13 years ago. The joint was *not* in a plane with the object, but below the surface of the stage, and the diaphragm was attached to a lateral slide, in order to make use of it when the mirror was hung obliquely, which is a clear proof that the joint was *not* in a plane with the object. I admit that in the way they accomplished it, they could have placed the joint higher, as they did in instruments brought into the Centennial Exhibition at a later time, but at a loss of extreme obliquity. To bring their mirror over the stage is utterly impossible.

A few days ago Dr. J. G. Hunt showed to me a letter received from Mr. W. H. Bulloch, of Chicago, accompanied by cuts and photographs. Dr. Hunt had the kindness to hand the photographs and cuts over to me, and I lay them before you. One photograph shows that Mr. Bulloch has adopted my circular, graduated, *adjustable* glass

stage, claiming this old invention of mine as his own. According to his statement he made it first in July, 1870, just 10 years after I introduced it.

The large cut and the other photograph represent his large Binocular Stand, also with adjusting screws to the adjusting revolving stage. The mirror stem is apparently stationary, and the mirror is attached to it by a double joint, permitting of some oblique illumination. But the important part of this instrument is an arc below the stage, which is traversed by the sub-stage. The centre of the arc is evidently in the plane with the object, and therefore the sub-stage can be placed radial to the object, provided the somewhat complicated mechanism is made and used with care. The angle of obliquity, of course, is a limited one, and even with a stage as small and thin as my Diatom Stage, it would not be possible to obtain, either with mirror or condenser, an angle sufficiently great for the present requirements. As the *mirror does not swing with the sub-stage*, it is difficult to get the mirror centered with the condenser. The photograph is marked 1873, making it evident that it is the first attempt to place the achromatic condenser in an oblique position to the optical axis. But comparing this arrangement with mine, as designed and adapted to my stands, the difference in the results, although involving the same principle, will be seen at once. The design of Mr. Bulloch is a heavy, costly attachment, limited in its movement, and unhandy, as the mirror does not follow the sub-stage, and when the mirror is used alone it is of no use whatever. In mine the mirror and sub-stage movement is only limited by the body of the microscope, and can be used below or above the stage, *always* having the object at its centre, and in such a simple way that not a single extra piece is added to an instrument with the ordinary swinging mirror; hence we can adapt it to our cheapest microscopes. Mr. Bulloch claims to be the first to use the mirror above the stage instead of the bull's-eye. According to his own statement, in 1870, I can only say, if Mr. Bulloch did not accomplish it before that time, that he is the last one I know of, who invented it. Spencer, Tolles, others and myself did the same thing many years before; and the little so-called Candlestick Stand, made and presented to our section by Mr. Ed. Tilghman, about 18 years ago, is capable of doing the same thing. Some accomplish it by detaching, others by adding, joints to the mirror. If accomplished in this way it is not worth the sacrifice of stability which is incurred.


H. SEBALD

DESCRIPTION OF ZENTMAYER'S AMERICAN CENTENNIAL MICROSCOPE STAND.

This stand was designed and constructed especially for the Centennial Exhibition. It is mounted on a tripod, with revolving platform. The bar and trunnions are one piece, and swing between two pillars for inclining the instrument to any angle. The swinging sub-stage, which carries the condenser (or other illuminating apparatus), and the mirror, swing around a pivot, the axis of which passes through the object observed, so that the object, in every position of the sub-stage, is in the focus of illumination.

The stage is attached to the stand by a spindle, which passes at a right angle through the axis of suspension of the instrument, and is firmly fastened in position by the milled head nut in front.

The large rotating stage may be removed and replaced by one especially constructed for extreme oblique illumination, called a diatom stage, and the swinging illuminator may then be used for illumination from above. The sub-stage is provided with a graduated circle (on the collar of the swinging arm) for indicating the degree of obliquity of illumination.

As an object placed on the stage is in a plane with the axis of the trunnions, it is obvious that, if the instrument is placed in a horizontal position, the object is in the axis of revolution of the graduated platform, and the angular aperture of an objective focused on this object can be easily measured. In this position the object is in the centre of all the revolving parts of the instrument, the revolving stage, swinging sub-stage, and the platform.

The principal stage is similar to that introduced by Mr. Zentmayer in 1860. It was the first stage provided with adjusting screws for accurate centering and revolving in a large outside ring, thus giving facility for oblique illumination and graduation to serve as a goniometer.

The sub-stage is divided into two cylindrical receivers, to facilitate the adaptation of several accessories at one and the same time; the lower cylinder of the two can be moved up and down or entirely removed.

The adjustable concentric diatom stage is 3 inches in diameter, and extremely thin, allowing, in connection with the swinging sub-stage and mirror, not only the greatest oblique illumination, but the mirror and achromatic condenser can be swung above the stage for illuminating opaque objects. B.

NOTES ON COMPENSATING-POWDER.

By Lieut. CHAS. A. L. TOTTEN, U. S. Army.

The construction of the 81-ton gun has been accomplished only through a masterly subjugation of the difficulties attendant upon great-gun manufacture. There are, however, very few insurmountable mechanical difficulties, and the success with which these have been met and subdued simply gives us new evidence of progress in modern art. But perhaps this is the chief merit that England can claim for her achievement, since it is doubtful whether as a *step* in cannon construction it possesses any other very valuable feature.

No *new*[i] ballistic principles were discovered during the experiments with it at Shoeburyness, nor was its origin founded upon any new theory of cannon manufacture. It is constructed of the same materials used in all English guns, is "built up" in a similar manner, uses the same explosive in proportional charges and grains, and gives evidence of possessing all the *disadvantages*, as well as the advantages, of its many predecessors. The hereditary weakness of this family of guns appears to be inevitable, and advices from abroad state that the interior tube of the 81-ton gun has cracked, thus early, in the same way as do those of all Woolwich cannon.[ii]

There is a definite relation existing between gunpowder and gun-metal, and gun strength or safety depends upon its due recognition. This relation must enter as a vital condition into the equation of every cannon, and as *definitely* into that of the great-gun, as it does into that of a toy. But no new conditions were impressed upon the Woolwich equation to realize the 81-ton gun; simply larger quantities were substituted and correspondingly greater results obtained.

The tables of fire as reported from these experiments at Shoeburyness, give no appreciable gain in initial velocity.[a] Such a deficiency, in so costly a gun, is noticeable from the fact that the safe

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[i] Several "re-discoveries" have been made, but no markedly new points have been brought out. See *Army and Navy Journal*, Vol. XIV, No. 21, page 329.

[ii] *Army and Navy Journal*, Jan. 20, 1877.

[a] As supporting this statement, see *Army and Navy Journal*, Jan. 27, and Feb. 24, 1877; and *Benton. Ord. and Gun.* Page 565.

Table 3, Roberts' Hand Book, latest edition (1875), gives 1561 feet I. V., as the

attainment of a greater initial velocity than has thus far been realized, is perhaps the vital problem of modern ballistics. Money has been persistently wasted in the vain endeavor to obtain valuable results from *defective* gun systems, while the important question of velocity would not seem to have received its due share of attention.

In view of the shortcomings of the 81-ton gun, this problem now presents itself with renewed interest, and urges us to lay aside for a moment the troublesome question of construction, and turn our attention once more to that of a *suitable* motor power.

The expression,

$$\frac{M V^2}{2g}$$

represents the energy of a projectile; in which M stands for mass, and V for velocity. If we cause either of its factors to vary, while the other remains constant, we will affect its value, and accordingly as V or M becomes the variable factor, the circumstances of impact will alter. In the one case we shall have the same projectile moving with varying velocities; in the other the velocity will remain the same, while the projectile will alter. Let M and M', V and V' represent respectively the masses and velocities of two similar projectiles, made of the same material. Let

$$\frac{M V^2}{2g} = \frac{M' V'^2}{2g}.$$

But let M be greater than M', then will V be less than V', and though the actual amount of work performed will be the same in both cases, it will be accomplished differently. The energy of the larger, heavier projectile, will be lost in the shock of impact, it being distributed slowly over a large surface, while that of the

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maximum, and the others ranging from 1000 to 1500 feet, for the British cannon that preceded the 81-ton gun.

Holley, in Table XXVIII, holds to about the same figures for the rifled guns, and to some 1600 for the smooth bore guns of the same service.

The initial velocity given by the larger Varvasseur guns (Table 5, Roberts), varies around 1200, 1400 or 1500 feet.

Similar initial velocities—1400 to 1500 ft.—are ascribed to the efforts of the Krupp gun. Table 6, Roberts.

We can, in fact, fairly assume that the initial velocity to be expected of a projectile, fired from the best guns, and with their proper service charges of *gunpowder*, can hardly exceed the normal one of 1500, or at the most, 1600 feet. Greater power exists in the powder, but we cannot afford to strain the gun and so have to sacrifice it.

smaller and swifter one, will be expended in penetration. There result from this consideration two great ballistic systems, known as the American or Racking system, and the English or Punching system. The former has to deal with mass, and endeavors to determine the largest projectile which can be impressed with a normal velocity; the latter studies velocity, and seeks to know the greatest initial impetus which can be imparted to a given projectile. "Smashing" effect is the desideratum of the one, penetration that of the other.

Other things being equal, it belongs to the punching system to improve gun strength and efficiency, while the racking system should study gun size and construction. These considerations, however, are almost the opposites of the ones that have determined the experiments of the rival schools. Strangely enough, each has seemed to be most interested in the problem of the other, and English experiment in particular, while it has not noticeably advanced the cause of the punching system, has clearly established the practicability of the racking.

The Woolwich gun has grown in size, but the relation between charge and projectile has had no opportunity to alter, and therefore very naturally the recent experiments at Shoeburyness, show no increment in velocity. The absolute effect is, of course, greater, but it is manifestly due to the racking element of its enormous projectile.

In the meantime, though America has done very little in the experimental line, she has carefully studied both systems. She is not ready to abandon her own, but has certainly decided favorably for rifling, breech-loading, and gun strength, all elements belonging to the punching system.

But all of this experiment and study has been based upon the supposition that the motor power has been perfected; that we have developed all the possibilities of gunpowder, and satisfactorily established the inadaptability of the detonating class of explosives, for artillery purposes, and that, therefore, we must accept gunpowder as the primary starting point in all future artillery improvement.

It was but a few years ago that grains of mammoth powder, less than an inch in diameter, were regarded as enormous. Its introduction into artillery use added a noticeable feature to its modern phase, but the step once taken suggested others leading to even more decisive results, until to-day we find the large-grained powder

thoroughly tested, and, in some form or other, generally adopted. So far from being surprised now at a cubic inch of powder, we deliberately handle and expend grains or masses weighing pounds. Improvement in gunpowder has kept pace with cannon improvement, until, practically speaking, the former has been perfected. Its proper composition has long been known, its most suitable grain-shape studied, its density thoroughly investigated, and the best methods of its manufacture pretty certainly arrived at. The phenomenon of its explosion is sufficiently well understood to make its use absolutely safe and certain. In its various forms of prismatic powder, pellet, hexagonal, perforated cake, and others, we find this fierce explosive agent handled in a way so masterly, that its almost lightning change of state from a solid to a gas is, practically speaking, under our control. Of course we do not mean that in these studies we may not to some extent still improve, but that it is a matter of reasonable doubt whether absolute perfection in all of them would materially increase its present power, and satisfy the demand for such a projectile agent as a 100-ton gun certainly requires.

Among the large class of explosives more violent than gunpowder, none, perhaps save gun-cotton, has been found in the least degree suitable for artillery use. They have been studied carefully, but all of them have been found too sudden in their action—they strain a gun too severely. Austria, indeed, almost curbed gun-cotton for artillery use, but, whether woven or granulated, its rate thus reduced in a wonderful degree, still even this, the most tractable of all the detonators, has proved more than a match for the best of guns, and, we understand, its special patron has at last abandoned it and returned to gunpowder as perhaps alone practicable.

It is of little consequence how great the absolute working power of an explosive be, provided we can regulate its application. Could we but concentrate the whole force of a charge of nitro-glycerine upon the projectile, there could be no better agent for artillery use, but how to do it is the question. It is not so much that a given gun will not sustain this or that pressure, but, that it cannot offer the same resistance to a *blow*, as to an increasing and continued pressure of even the same intensity. For instance, a gun which would burst disastrously under a pressure of 50,000 lbs., due to the explosion of nitro-glycerine, might stand the same pressure from one of gun-cotton, and possibly be quite within the limits of safety for an equiv-

alent charge of gunpowder in its most approved form. The dangerous element in the phenomenon of explosion is its *rate*.

Philosophers have confidently asserted that, rapidly as it moves, the earth could be put in absolute rest, and without shock, in a few minutes. Everything is relative. So, too, in the phenomenon of explosion, can we but govern it during its brief duration, so that its action shall be an *acceleration* instead of a *shock*, we shall solve the first problem of modern artillery. This problem is to find an explosive of such capacity and character, and in such form and condition, as will give a maximum impetus to the projectile while it exerts a minimum strain upon the gun. Primarily, then, it must be an accelerator, a composition such that, while it possesses all the energy of the detonating class, shall nevertheless curb that energy in the first instants of its action, and concentrate it upon the projectile. It can rule the projectile but a moment; this moment over, its influence is but a dying echo. In this brief instant the projectile must rise in a relatively gradual scale through all the stages, from absolute rest to great velocity. If this can be accomplished, it is manifest that for the same charge we shall strain the gun less. We shall focus, as it were, the whole force upon the projectile, and for the same reason the latter will receive the utmost velocity that the given charge can impart. From this standpoint the action of gunpowder is best studied under the form of the perforated cake, which we will briefly examine.

Explosion in the case of gunpowder is a true combustion: it burns regularly inwards, though rapidly, layer by layer. The amount of gas developed depends directly upon the extent of the burning surface. If the size of the grains be increased while the weight of the charge remains constant, there will be less surface exposed to combustion, and the amount of gas evolved in the first instants of time will be diminished; consequently there will be less pressure on the breech of the gun. This principle led the late General Rodman to perforate powder grains of large size with numerous small holes, for the passage of the flame. The powder thus burns upon an increasing surface, the gas continually gains intensity, the gun is not so severely strained, and the normal velocity is retained. Here, then, is a true accelerator.

The latest American powder, hexagonal, and the English, cubical, the latter used in the 81-ton gun, are steps in retrograde. They are

not accelerators—this principle has been sacrificed to the attainment of density and uniformity. These forms of powder beautifully illustrate the relation between a large surface of combustion, and a diminished strain upon the gun, and thus fulfil their mission; still they are but temporary expedients. It is different, however, in the case of the perforated cake. Powder thus treated conserves its force well, and strains the gun towards the minimum, and for this reason it has very naturally been adopted by one of the greatest military powers in Europe, for use in the strongest gun. In the meantime, with the detonating class of explosives we have been mainly engaged in reducing the intensity of their action. nor have any of them yet come within the limits of artillery requirements. Explosion in the case of gun-cotton is not combustion: it is more of a disintegration, a loss of equilibrium, taking place, as it were, instantly throughout the entire mass; the outer portion does not seem to protect the interior, as is the case in a large grain of gunpowder.[b]

Gunpowder and gun-cotton are respectively the best representatives of the two great classes into which explosives may be divided—mechanical mixtures and chemical compounds. We have briefly referred to them separately; let us now glance at them comparatively, and follow the suggestions of their study to some legitimate conclusion.

Gunpowder ignites at about 570° F., while gun-cotton will explode at 360° F.; the former may be used as an igniter for the latter. Equal weights of the two substances can be put in such condition as to occupy about the same space. They are chemically neutral to each other. As to absolute force, gun-cotton is from 3 to 7 times more powerful than powder, weight for weight.[i] They are both

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[b] There are two orders of explosion, and gunpowder and gun-cotton are each susceptible to both; the former, however, favors true combustion, while the latter is most liable to detonate. * * * * Ordinary explosion is the mechanical progress of an impulse from atom to atom of the substance itself; detonation is the rapid transmission of this impulse through some other medium, as it were, and reaches all the atoms practically at once—in the one case we have successive, in the other, instantaneous action. "The rapidity with which gun-cotton detonates has been computed at 20,000 feet per second." (Knight.) "The velocity of combustion of dry French war powder is found to be 0·48 inches, and of English powder, which American powder closely resembles, about 0·4 inches." (Benton.)

[i] "In experiment with a Krupp's, cast steel, 6 pounder, a service charge of 30 oz. of powder produced an initial velocity of 1338 feet; a charge of 13½ oz. of gun-cotton produced 1563 feet."—*Holley. Ord. and Armor*, 793.

We regard gun-cotton in this paper as having an intensity 4, gunpowder being

stable substances; neither of them is subject to serious change under ordinary atmospheric conditions, and of the two, *gun-cotton* is the least alterable from such influences. Relatively speaking, gun-cotton is no more liable to explode from friction or percussion than gunpowder; these substances are, in fact, the safest of their respective classes, and gun-cotton itself is by no means the *dangerous* substance generally supposed.[c]

Both of these explosives possess valuable resources for the artillerist, yet neither of them fulfils in itself all the requirements of a projectile agent. While powder has considerable, gun-cotton has almost unlimited power; the explosion of the former can be governed, that of the latter has hitherto been unruly. But the very means we take to curb the first-force of powder, reduces to a minimum its already relatively small power-capacity. If we could obtain an explosive whose action would be similar to that of hexagonal powder until the projectile had taken up a rapid velocity, and which should then burn up with all the energy of gun-cotton, we would have a most valuable accelerator.

"How can these two substances—gunpowder and gun-cotton—be used in combination?" This question, asked of the writer by a brother officer some years ago, suggested a method which resulted in a joint invention that has received the name of "Compensating-Powder."[d] The idea is to "build up" grains, cakes, or masses out

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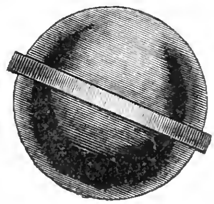
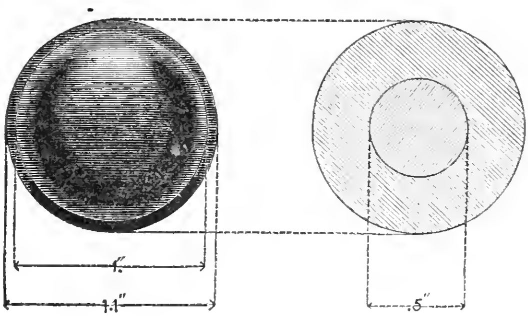
unity. It must be noticed, however, that in the employment which we shall make of this material, its relative force (as a minimum) is of but little consequence. Gen. von Lenk has discovered the means of giving gun-cotton any velocity of explosion that is required, and any force from one to seven. This depends upon its mechanical condition. Abel's disk may be much more powerful than Austrian woven, or spun gun-cotton, and the more powerful the better for our purpose.

c It must of course be understood that we are discussing these substances under their most reliable and latest known conditions. Of the stability of *good* powder there can be no doubt; of that of gun-cotton, in similar condition, we have unimpeachable assurances from the highest authorities. See notes on explosives by Prof. Hill, and testimony of Baron von Lenk, the famous Austrian experimenter on gun-cotton, before a special committee of the British Association, on the characteristics and explosive properties of this substance. See *Report of British Association*, 1863.

d The compensating-powder was discussed at the Artillery school several years ago, it being the joint invention of two officers (1st Lieuts. A. E. Miltimore, 1st Artillery, and Charles A. L. Totten, 4th Artillery, U. S. Army), then on duty with the class at Fortress Monroe. The matter lay in its crude form for some time, owing to changes of station and press of other duties, until the detail of the writer to this institution,

of two or more explosives, or out of the same explosive in varying conditions, in such a manner that these explosives shall be ignited *successively* by the actual combustion of the several layers down to them. For instance, suppose we have a large grain of such powder; its form, for discussion, is immaterial; let it be a sphere of gun-powder an inch in diameter, and imagine it to possess an interior and concentric core of gun-cotton one-half an inch in diameter. Such





a grain would be constructed with a scientific regard to the peculiar characteristics of each substance, and would evidently burn upon the accelerative principle. Let us examine the theoretical combustion and effect of a charge of such powder fired in a gun. The relative amounts of the two explosives would satisfy the demands of the compensating principle (to be noticed later) and at the same time the

offered special facilities for study, the consultation of scientific men, and the further development of the idea. It is still more or less theoretical, and while both of these officers fear that it is, perhaps, published too early, still the step is rendered advisable for many reasons known best to themselves. It is worthy of being fairly examined by military men, as at least an interesting attempt at the solution of an important problem, and one that, even should it fail to realize its own promises, may suggest to others the direction in which to take this all-decisive step in modern artillery—the one in search of greater initial velocity, coupled with a minimum strain upon the gun.

reasonable precaution of reducing the more explosive substance to its minimum effective quantity. Immediately after inflammation the gunpowder would commence to be rapidly consumed in towards the cotton. The exterior layer burning first would prepare the way for the more violent explosion of the interior one, and being itself in large grains, would offer a minimum surface to combustion during its first and most decisive instants. The powder part of the grain would thus be suited to large charges and guns.

It takes but a few one-hundredths of a second for all the powder to be consumed. In the meantime the projectile will have acquired its motion as in the case of the ordinary charge of powder alone, for thus far there has been no difference in the explosion, and will have reached a point in the bore beyond which, with powder alone, no material gain is to be realized from gun length. The small amount of powder which would now remain unconsumed, were the grain homogeneous, would barely evolve gas rapidly enough and in sufficient quantities to fill up, or *compensate* for, the increasing space behind the projectile, and would, of course, be useless for acceleration. For all practical purposes a powder grain might as well be *hollow* from this point inwards. But just here the valuable part to be played by the interior core of the compensating grain is to be noticed. Exploding at this moment with great rapidity and force, it checks any tendency of the gas to lose its tension, compensates for the increasing space in rear of the projectile, and, indeed, actually gives it a final and valuable accelerating impetus. The great force thus developed by the gun-cotton in this last stage will not be exerted against the walls of the gun, as would be the case in the explosion of a charge of gun-cotton alone, but will evidently be directed towards the line of least resistance thus artificially prepared for it. The cotton, in fact, will find a condition of affairs in the bore of the gun that is especially favorable for its action. It is no longer confined to a space just sufficient to contain it before combustion, but finds a continually increasing one into which to expand, a cushion of gas against which to impinge, and an already rapidly moving projectile to accelerate. In the summer of 1876 the residence of Prof. Gœssmann, at Amherst, Mass., was struck by lightning, which in its course through the house paid a very marked deference to one of the fundamental laws of force. The fluid came down the chimney, burst out into a second story room, *and passing along the gilt border of the wall-paper*, bored its way through the

opposite side of the house without deranging the room in the slightest. The inappreciably thin metallic layer of this gilt border was all-powerful! If lightning, a force so violent and swift, is still obedient to this simple law, it is obvious that the explosive impetus from the interior core ought likewise to seize so opportune a line of least resistance.

In the employment of mammoth powder, even in its most approved form, we have to contend against a very serious element—*wastage.* These large grains are found to be only partially consumed; still burning, they are thrown out of the gun along with the projectile. That is, when the combustion has reached a certain point the projectile leaves the gun, and all the powder remaining unconsumed is wasted. This waste reaches the enormous amount of 60 per cent.! The introduction of an interior core of higher explosive properties can be made to do away with this expensive loss. Forty pounds of powder do all the work in a service charge of one hundred pounds.[i] Reckoning guncotton as only four times the strength of gunpowder, fifteen pounds of it would be equivalent to the sixty pounds of powder that are wasted. If, then, we imagine this amount of cotton introduced as a core into the forty *working* pounds of powder (the size and number of grains remaining the same), we shall have a charge stronger, by the equivalent of sixty efficient pounds, than the present service charge of the 15-in. "Rodman gun." It must be remembered, moreover, that such a charge will expend its first forty pounds in impressing the projectile with its present normal velocity (1500 or 1600 feet), and that the remaining fifteen pounds (*once and a half the value of the first forty*) of force generator, will work under the most favorable circumstances as a pure accelerator. We shall thus eliminate the great waste of the one, curb the straining action of both, and obtain a true *artillery powder*,—lighter, and four and one-half times more effective, charge for charge, than our best gunpowder.[ii]

(To be continued.)

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[i] In this calculation we have taken a low estimate. "Bunsen and Schischkoff determined that the waste in gunpowder is 68 per cent. of its own weight, and that only 32 per cent. is useful. In a 100 lb. charge, a portion of the 32 lbs. of the useful powder-gas must be employed in impelling a 68-lb. shot composed of the refuse of the gunpowder itself."—*Holley. Ord. and Arm.*, 789.

[ii] So long as we use gunpowder, we must, of course, contend against an unavoidable percentage of waste, but regarding this (which we do here to simplify the argument)

Osmotic Action in Fishes.—When fishes are removed suddenly from fresh to salt water they generally die. Felix Plateau thinks that the sea-water acts as a poison, but Paul Bert attributes their death to osmosis. A frog, plunged in sea-water, loses a third of his weight; if only the paw is immersed, blood globules escape from the vessels and spread under the skin. Salmon, in such a sudden change, live longer than most fresh-water fishes, but they succumb after five or six hours. Hence it is probable that, in their migrations, they gradually accustom themselves to the changing density of the water. Fresh-water eels are exceptions to the general rule. M. Bert cites a fact which shows how easily errors may be made in laboratory experiments. He had repeatedly plunged fresh-water eels in salt water, and having always found them alive after many days, he left the experiments to his office boy, when he found that the eels always died within three or four hours. On investigation he found that his boy took the eels in a napkin, and thus wiped away some of the mucus, which commonly protects the skin from the injurious effects of the water.—*Les Mondes*, March 29. C.

Water-tight Cement.—A good waterproof cement is made by dissolving five parts of gelatine in hot water, and adding one part of chromate of lime. The cement must be kept in vessels which are well shielded from light.—*Der Practische Maschinen Constructeur*, 1877, No. 5. C.

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as coming entirely (as it does mainly) from the loss of the unburned portion, we have the means of eliminating it. If, however, we are to argue strictly, then, allowing 18 spheres to the pound, we have 388·8 grains as the weight of each, of which 58·3 grains are the weight of the core, and 330·5 that of the jacket. Were this a homogeneous sphere of powder, 40 per cent., or 155·5 grains, would do all the work and 233·3 be wasted. But reckoning the relative value of cotton as 4, the core of this sphere (none of which is wasted) is equal to 233·3 grains of powder, and as 132·2 grains of the powder jacket *are* effective, we have 365·5 grains as the effective powder-value of this sphere. If we take cotton at 7, we have for this value 540·0 grains! In the one case we have an absolute loss of only 23·8 grains, in the other an absolute gain of 151·2; in the former we have a *relative* gain of 210·0 grains' work, in the latter, one of 384·5.

So many conditions, which do not at first appear, will enter this problem, that to consider the question in its mathematical bearings alone would require all our space. No attempt is made, therefore, to elucidate the intricate questions of relative size of jacket and core, their resulting densities, the dependent rates of combustion, etc., etc. These are all intimately related to each other and to the general question, and will be studied with interest by those who wish to investigate this matter of *compensation* deeper.

CONCERNING INDICATOR DIAGRAMS.

By Paul Kauffer.

[Translated from *Dingler's Polytech. Journal*, by Henry H. Suplee, S. B.]

In the majority of writings upon the steam engine, diagrams are used just as they are taken by the indicator, but this is not altogether correct. For the simple calculation of the gross power of an engine, the diagram may be used in its original form, but not if it is desired to ascertain the effective pressure exerted upon the piston at every point of the stroke; as, for example, when it is desired to determine the proper mass for the beam, fly-wheel and other moving parts, that they may have sufficient inertia to overcome the inequalities of pressure.

Fig. 2.

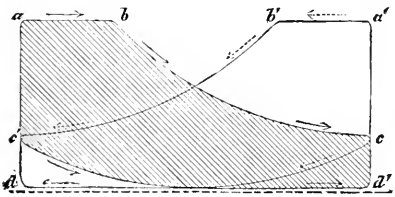
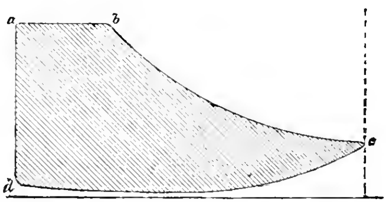


Fig. 1.



Every diagram consists of a curve of work and a curve of resistance, and these two curves are not traced at the same time; but, for example, the curve of work is taken in the passage from left to right, and the curve of resistance in the return from right to left. In order to indicate a working cylinder, I use, wherever it is possible, an indicator on each end of the cylinder, and it was the analysis of just such a case that first showed me the necessity of the following correction:

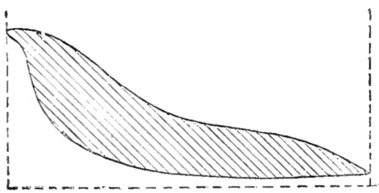
In Figs. 1 and 2, I have endeavored to show the case as clearly as possible. The valve was set quite correctly, and the diagrams from each end were very similar. The diagram from the left end, Fig. 1, is marked in Fig. 2 by the letters *a*, *b*, *c*, *d*, and that from the right end by the letters *a'*, *b'*, *c'*, *d'*. It must now carefully be noticed that during the stroke of the piston from left to right, the curves *a*,

b, *c*, and *c'*, *d'*, will be drawn simultaneously. There is, therefore, at the beginning of this stroke, a pressure upon the piston equal, not to *a d*, as in the uncorrected diagram, but to *a c'*; and the back pressure at the beginning of the stroke will no longer be null, as in Fig. 1, but will be equal to *c' d*. The arrows show the direction of the stroke from that point, moving from left to right.

Of course, the correction is just the same for the right hand diagram, as shown by the dotted arrows. The difference is now quite apparent between the shaded diagram of Fig. 2 and the uncorrected diagram of Fig. 1. If the valve is carefully set, so that the diagrams from both ends are alike, it is a very simple matter to make the correction, as it is only necessary to reverse the resistance curves.

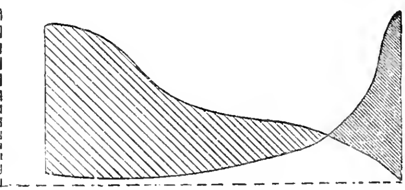
I give some further examples, in order to show the value of this correction. Fig. 3 is a diagram from Bauschinger's "Indicator Ex-

Fig. 3.



Original.

Fig. 4.



Corrected.

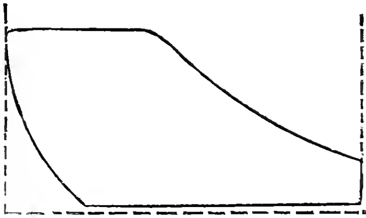
periments on Locomotives," and Fig. 4 shows this diagram as corrected. A single cylinder would hardly be able to make such a diagram at all, as the mass of the moving parts would have to be disproportionately large in order to store up enough living force at the beginning of the stroke to overcome the resistance at the end, as shown by the dark shading of Fig. 4. According to Fig. 3, the curve of work could hardly be more uniform, but in Fig. 4 it is quite otherwise.

With Fig. 1 the case is just the reverse. A balance-wheel, calculated from Fig. 1, would be much too heavy, since the variation of pressure appears much greater in Fig. 1, than when corrected in Fig. 2.

This correction would soon relieve many engines of the unnaturally high compression with which they are working. A glance at Fig. 4 shows the injurious effect of such compression. In order to show this

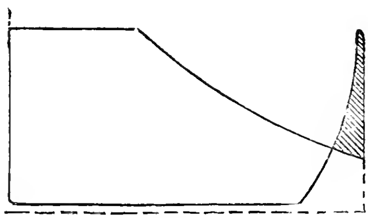
by some examples, I have taken Figs. 5 and 7 from Radinger's

Fig. 5.



Original.

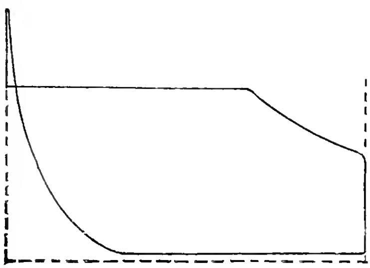
Fig. 6.



Corrected.

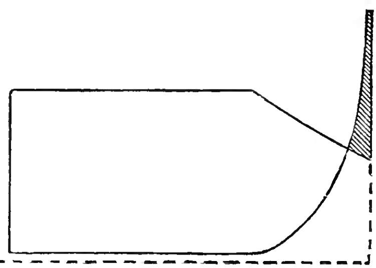
valuable work on the steam engine. These two diagrams are given just as they were taken from the engine. By their side I have

Fig. 7.



Original.

Fig. 8.



Corrected.

placed the corrected diagrams, and I will leave it to the reader to judge whether such compression is as advantageous as it seems to have been considered till now.

Recovery of Platinum.—Mons. E. Duvillier recommends the following method of reducing the platinum from the chloroplatinate of potassium: 100 grammes of the chloroplatinate, 50 grammes of dry formiate of soda, 50 c. centimetres of soda at 30° B.; boil in about 1 litre of water.—*Acad. Sc.*; *Les Mondes*, March 15. C.

Cure of Chronic Anæmia by Transfusion of Blood.—M. Oré reports a case of anæmia of five years' standing, induced by nervous and digestive troubles, which was effectually cured by the transfusion of 40 grammes of blood. He considers the blood as acting in two ways: 1, by stimulating the action of the enfeebled organs; 2, by favoring the growth of new globules. C.

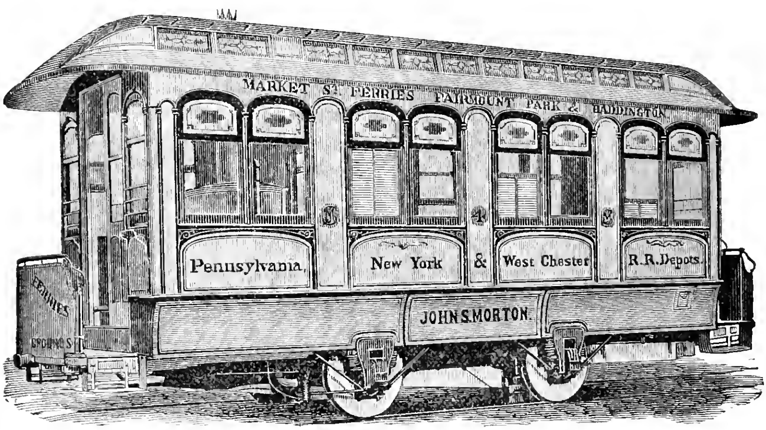
STEAM ON STREET RAILWAYS.

II.

Extract from the Secretary's Report, at the Meeting of the Franklin Institute, May 16th, 1877.

In furtherance of the proposition to lay before you such information as is available regarding the progress making toward the general introduction of mechanical propulsion on street railways, you are here presented with illustrations on the screen, of the steam street car invented by Mr. Louis Ransom and built by Messrs. Gilbert, Bush & Co., of Troy, N.Y. Six of these cars (Fig. 1) were placed on the Market Street line in this city on March 21st, 1877, and

Fig. 1.



have run with considerable regularity to this time, over what is known as the Baring Street branch, which has maximum grades of about four and one-half per cent., and many curves.

These cars are 16 feet long in the clear inside, and have a seating capacity for 20 persons, but are very frequently loaded with 50 persons.

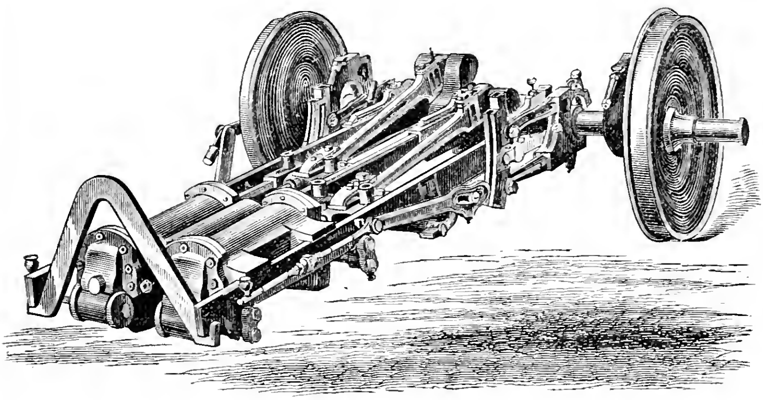
They have a wheel base of 7 feet, rather more than the ordinary horse-car, by which it is claimed there is less *teter* in passing over rough or uneven places in the track, although it increases the friction in passing curves.

The boiler is upright, with shell 37″ diam. by 56″ high, made of one sheet of No. 1 charcoal hammered iron, and contains 300 upright

tubes $1\frac{1}{4}''$ diam. and $12''$ long, and has 116 square feet of heating surface and $6\frac{1}{2}$ square feet of grate. The boiler is tested to 200 lbs. pressure per square inch, and its working pressure is 120 lbs. The steam room in the boiler is 26 times the capacity of one engine cylinder.

The engine (Fig. 2) is a double one, having steam cylinder $5\frac{1}{4}''$ diam. and $14''$ stroke. The two cylinders are cast in one piece, and have attached to them three bars which extend to, and are connected by journal boxes to, the crank axle, thus forming the framing of the engine. By this arrangement all the working strain of the machinery is brought on these bars or frame, and not on the frame of the car body. The slide valves are operated by a link motion and two eccentrics to each cylinder. The link is not raised or lowered as in the more general practice, but oscillates on a pin at one edge and midway of its length of the link. The valve rod is attached to a

Fig. 2.



pin in the link block, which is moved up or down to reverse the engine or vary the rate of expansion. The reversing lever is placed in the corner of the car in front of, and convenient to, the engineer's right hand. One end of the engine is supported by the crank axle, which is placed at the after end, and the forward or cylinder end of the engine is supported by a bale passing over a strong bar attached to the bottom of the car body. The usual straight axle supports the forward end of the car, but its wheels are not coupled to the driving wheels. The whole propelling apparatus, being supported at three points, is not easily racked or injured by derailment, gives great flexibility and is easily removed in case of extensive repairs; when

slight repairs are needed the car can be run over a pit, the front end of the engine detached and allowed to hang down from the crank axle like a pendulum. The machine is also accessible for cleaning, oiling, packing, etc., through trap-doors in the floor of the car.

There is attached a steam brake with a cylinder $3\frac{1}{2}$ inches diameter and 8 inch stroke. The piston rod is extended into a rack which works in a geared sector. From pins in the sector, connection is made by links to knuckle-jointed levers, forcing the brake shoes against the inner edges of the wheels. The lever of the brake throttle is so arranged with reference to the engine throttle lever, that the act of shutting off steam from the engine, opens the brake throttle, thus enabling the engineer to perform both these acts with one short stroke of the hand. The boiler is placed a little forward of the front axle and the water tank under the floor at the rear end. The space for passengers is about equally divided forward and aft of the hind axle, so that their weight nearly all comes on the driving wheels. The noise of the exhaust is quieted by passing the steam through a muffler consisting of a box of considerable size filled with balls or pebbles.

Mr Ransom differs from the view expressed at the last meeting of the Institute, regarding the use of the crank axle, and holds that all the English, and many American Locomotives are still built with inside connections; that they impart a much steadier motion than outside connections; that the crank axles do not prove essentially weaker than the straight ones; that outside connections cause a vibrating motion to the car at high speed, and have no advantage except ease of access to the working parts.

He places great stress upon the injury done to the machinery of all steam street cars, from its exposure to the dust of paved streets, and estimates the cost of repairs from this cause alone (if not guarded against), as a large percentage of the entire cost of operating such cars. To overcome this he has enclosed the machinery in a box or casing so perfectly dust-tight, that after running all day through the dusty streets, the engine is not only free from dust, but covered with drops of water, condensed from the slight escape of steam from the stuffing boxes. The facility with which the machinery can be so enclosed, to protect it from dust, he claims as another advantage in the use of the crank axle for street cars.

These engines can be applied to old car bodies, as it is only necessary to raise the rear end of the car so as to run out the axle,

and put the engine crank shaft in its place, and attach the front end of the engine to the bottom of the car; provision would of course have to be made for the boiler.

In January, 1876, one of the Ransom steam cars was put on the Coney Island Railroad, extending from city line to Gravesend, a distance of $4\frac{1}{2}$ miles, where it run 81 miles per day for 5 months. The round trip of 9 miles was run in 40 minutes, and then the car stood 50 minutes. The consumption of coal was 600 lbs. per day, or 7·4 lbs. per mile. This car was submitted to severe trials before and after its regular work at Coney Island, and was afterwards sold to, and is now running on, the Onondaga Valley Road, in Syracuse, N. Y.

The question of consumption of coal by the cars now running on the Market Street line, has not yet been determined satisfactorily, but Mr. Ransom hopes that it will be less than that mentioned above. The entire cost of running 81 miles per day, is, however, estimated at $8.31 per day.

Some difficulties have been encountered in running the present cars on the Market Street road, which the inventor says arose principally from two causes. First, he expected to have them run on the main line, and did not know of the many curves and steep grades of the Baring Street branch, over which these are running, and the $5\frac{1}{4}$ inch cylinders proved to be too small; they should have been 7 inches diameter, and the builders are now making them of that size for such service. Second, the peculiar, greasy mud of such a city as this, causes the ordinary chilled, cast-iron wheels to slip, and to overcome this, he purposes hereafter to use steel tires on the driving wheels.

When these and some minor changes are made, the inventor is very confident that his steam cars can be operated at a cost greatly below that of horse cars.

French Railway System.—In a memoir of M. de Franqueville, M. F. Jacqmin reviews the relations between the railways and the State, in different countries, coming to the conclusion that France alone has solved the difficult problem of reconciling these two grand principles: authority and liberty. The whole territory of France is divided into six grand railway-departments, in each of which, with a few unimportant exceptions, all the railways have been conceded to a single company.

Office books, very well devised, define the rights of the State and those of the company. Free to move within prescribed limits, the administrative councils and their immediate subordinates strive to develop commercial relations, or even to create them where they do not already exist.

In each department the different modes of technical working, the improvements to be made in the rolling stock, the questions relative to maintenance, to beneficial funds, and to retiring pensions for a clientage of more than 200,000 men, are all daily and carefully studied under different aspects, the very diversity of view furnishing guarantees of true progress and success.

At the same time the State, invested with important rights, by those same office books, exercises a continual surveillance over the companies. By the engineers of control and the subordinate commissioners, it is informed of the least incident which occurs on the roads. No tax is collected without having been confirmed, that is to say, without it has been shown by thorough examination that it is according to the conditions of the contract. By inspection of the finances the State penetrates into all the details of the combined action of the companies.

In time of peace the State is thus in a position to intervene at any instant, in the management of the railway companies, and to protect the public, if necessary, against monopoly. In time of war the immense property of the companies, together with their numerous disciplined and systematized corps pass under the control of the State; the workshops of the companies, true arsenals, are ready to execute the most difficult commands, to grind wheat and to make arms.

In fine, in 80 years, the entire network, which will have cost nearly $3,000,000,000, will be completely redeemed; all the capital and bonds will be reimbursed by annual levies on the working receipts, and the State will enter into full possession of a property sufficient to extinguish the public debt.

This system of equilibrium between the State and the companies, which the English call the "French System," may thus briefly be defined:

The association of the State and the companies, formed in order to assure the completion of the national network of railways, the advantages of the prosperous lines being partly employed for the benefit of the unproductive lines.—*Ann. des Ponts et Chaussés*, April, 1877.

C.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CIV. AUGUST, 1877. No. 2.

Franklin Institute.

In accordance with Article XII, Section 1, of the By-Laws, no meeting of the Institute was held in July.

The following donations to the library were received, and reported at the meeting of the Board of Managers, held July 11th, 1877.

Forty-first annual report of the Executive Committee of the Young Men's Association. Buffalo, N. Y., 1877. From the Association.

Statistics of the American and Foreign iron trades. Annual Report of the Secretary of the A. I. & S. Association. Philad'a, 1877. From the Association.

Specifications and drawings of patents issued from the U. S. Patent Office for December, 1876, and January, 1877. Washington, 1877. From the Patent Office.

Narrative of the North Polar expedition, U. S. Ship *Polaris*, Chas. F. Hall, Commanding. By C. H. Davis, U. S. N. Washington, 1876. From the Navy Department.

Tenth report of the Provost to the Trustees of the Peabody Institute. June 1st, 1877. From the Institute.

Tableau statistique des chemins de fer de la Suède, de la Norwège et du Denmark for 1875.

Annual report of the Commissioner of Patents, with Index of Official Gazette and monthly vols. for 1876. Washington, 1877.

From the U. S. Patent Office.

United States trade-mark statutes, and rules of practice in trade-mark cases in the U. S. Patent office, January, 1877.

Rules of practice in the U. S. Patent Office, November, 1876.

Rules of practice in interferences in the U. S. Patent Office, November, 1876.

Patent Laws, August, 1876.

Decisions of the Commissioner of Patents and U. S. Courts, 1871-1876. From Patent Office.

Annual report of the Chief of the Bureau of Steam Engineering for the year 1876. Navy Dep't. Washington, 1876.

Report on safety-valve tests, made at the U. S. Navy Yard, Washington, D. C., Sept., 1875. Washington, 1877.

From the Bureau of Steam Engineering.

Forty-fourth annual report of the Royal Cornwall Polytechnic Society, 1876. From the Society.

Haus- und Landwirthschafts-Kalender des landwirthschaftlichen Vereins in Bayern. 1877.

Abhandlungen de K. K. Geologischen Reichsanstalt. Vol. 9. Wien, 1877. From the K. K. Geol. Reich.

Germanischer Lloyd. Deutsche Gesellschaft zur Classificirung von Schiffen. Internationales Register, 1877. From John Haug.

Useful Information for Engineers, Boiler Makers and Firemen, by W. B. LeVan. Philad'a, 1876. From the Author.

The Sciopticon Manual. By L. J. Marcy. Philadelphia, 1874. From the Author.

Practical Treatise on Lightning Protection. By H. W. Spang. Philad'a, 1877. From the Author.

Lessons in Electricity at the Royal Institution, 1875–6. By John Tyndall. New York, 1877. From C. W. Myers.

Report of the Chief Engineer, J. W. King, U. S. N., on European Ships of War. Washington, 1877. From the Author.

Geological survey of Canada. Report of progress for 1875–76. From the Director of the Survey.

Histoire des recherches sur la Quadrature du Cercle, par Montucla. From W. P. Tatham.

Continued from July number.

Eighteenth annual report of the trustees of the Cooper Union, for the advancement of Science and Arts. May 29th, 1877. N. Y. From the Union.

Bulletins of the United States Geological and Geographical Survey of the Territories. Vol. 3, Nos. 2 and 3. Wash., 1877.
List of elevations, principally in that portion of the United States west of the Mississippi River. 4th Ed. By H. Gaunett. Wash., 1877.
Bulletin of the United States Entomological Commission, No. 2. Wash., 1877. From the Dept. of the Interior.

J. B. Knight, *Secretary.*

Attraction and Repulsion.—Wüllner has experimented with Geissler tubes, supplied with air and other gaseous substances. In all cases the electric column undergoes an attraction under a pressure of 4 to 12 millimetres, and a repulsion under a pressure of 1 to 2 millimetres. Between these extremes there is a neutral point, at which neither attraction nor repulsion is observed. Some experiments with the electric egg confirm Prof. Peirce's theory with regard to the formation of comets' tails, while the change from attraction to repulsion, and *vice versa*, may find a satisfactory physical explanation in the theory of Prof. W. A. Norton.—*Les Mondes; Acad. Imp. de Vienne.* C.

Specific Electric Action on the Radiometer.—In his third paper on the movements of radiating and irradiated bodies, F. Zöllner shows that the galvanic current not only affects the mica discs of the radiometer through the heating of the conducting wires, but that it also exerts a specific influence upon the surrounding gaseous medium, which is directly opposed to the effect produced by the increase of temperature. If the experiments of Edlund (Pogg. Ann., cxlix, 99), Streintz (Ib. cl, 368), and Exner (Wiener Ber., May, 1873), are confirmed, the galvanic current possesses an analogous specific influence relative to the expansion of bodies; for according to those experiments, a galvanic conducting wire expands more than it ought in consequence of the heat that is developed in it.—*Pogg. Ann.*, clx, 463. C.

TRACTION OF LOCOMOTIVES.

In the construction of many of our railroads over the mountains, various expedients have been adopted to work the lines before final completion, which have given us much valuable information in regard to working heavy gradients. On the Baltimore and Ohio Railroad, before the completion of the Kingwood Tunnel, the cars ran over the mountain on a gradient of 1 in 10, or 528 feet per mile. The engines used to work these grades were known as camel-backs, and weighed, when in running order, 24 tons—all of the weight resting on 8 driving wheels $4\frac{1}{2}$ feet in diameter; size of cylinders 17×24 inches. The tender, with a full complement of fuel and water, weighed 13 tons. These engines would take up this steep gradient of 1 in 10 an eight-wheel flat car loaded with iron rails, total weight of car and load, 13 tons. The speed obtained was about 12 miles an hour.

The Mountain Top Incline on the Virginia Central Railroad, crosses the Blue Mountains at Rock Fish Gap in Virginia, at an elevation of 1885 feet above the sea. The maximum gradient is 1 in 17·86, and the minimum gradient, with a single exception, is 1 in 22·22. The engines, chiefly, to work these grades have 6 drivers $3\frac{1}{2}$ feet in diameter, length of wheel base 9 feet 4 inches, cylinders $16\frac{1}{2} \times 20$ inches, and weigh $24\frac{1}{2}$ tons. In working steep gradients, the adhesion has in many instances been found equal to $\frac{2}{5}$ of the weight upon the driving wheels.

Mr. Zerah Colburn, with an engine weighing 26·8 tons, 19·2 tons on 6 driving wheels, has drawn a train of 50 loaded eight-wheeled wagons, weighing upwards of 756 tons, up a continuous incline two miles in length of 1 in 132. So far as it has been possible to trace the construction of the locomotives having the greatest percentage of adhesion, the length of the stroke has been from 1·30 to 1·45 times the diameter. It is believed that the adhesion of the driving wheels is largely influenced by the manner of admitting steam to the cylinders, as well as the speed and weight of the engine.

From a large number of experiments made with the dynograph, by Mr. P. H. Dudley, on different roads, with engines of short stroke, the adhesion is found not to exceed one-third of the weight on the drivers, and in many cases but little over one-fourth.

As opportunity shall offer, Mr. Dudley will continue these experiments, to determine what may prove to be a very important factor in the economical working of locomotives. K.

Warming and Ventilation.—Flavitsky uses double windows, placing an air-chamber under each window, into which the fresh outside air is admitted, and heated by ribbed tubes, by means of water or steam. The hot air rises between the windows, and enters the room near the ceiling.—*Ann. du genie civil*, July, 1876; *Zeits. des Arch. u. Ing.-Ver. zu Hannover*, xxiii, 298. C.

Economy in Steam Engines.—M. O. Hallauer has published a report of experiments upon steam engines, with saturated and with superheated steam, under various conditions. One of the most important results seems to be the demonstration of the importance of the exchanges of heat between the steam and the walls of its receptacles. By making proper allowance for such exchanges, a remarkable accordance is found between theoretical and practical values. Superheated steam gave a saving of 23 per cent., over saturated steam. The condenser realized an economy of 43 per cent.—*Bull. de la Soc. Ind. de Mulhouse, l. c.* C.

Improved Mortar and Artificial Stones.—M. Decourneau attributes the cracks in common mortars and cements, to the uncombined quicklime that they contain. In order to neutralize the lime, he uses an *agrégat*, composed of a very fine siliceous powder mixed with diluted nitric acid. He thus obtains mortars with much greater, more uniform and more lasting resistance than those hitherto used. The application of his method, especially in the new forts of Paris, has given excellent results, without a single failure. Stone made by his process, may be sawed and chiseled like natural stone.—*Soc. d'Enc. pour l'Ind. nat.; Les Mondes*, May 24. C.

Packing Paper.—Packing paper may be made water-tight by dissolving 1·82 pounds of white soap in one quart of water, and dissolving in another quart 1·82 ounces (Apothecaries' weight) of gum arabic, and 5·5 ounces of glue. The two solutions are to be mixed and warmed, the paper soaked in the mixture, and passed between rollers or hung up to dry.—*Fortsch. der Zeit.*, May 15. C.

Vegetable Leather.—M. A. Müntz has found that nitrogenous vegetable tissues are able, like the skins of animals, to absorb and fix tannin, and thus acquire a greater consistency, which forms a sort of vegetable leather. The amount of fixed tannin depends upon the amount of nitrogen in the vegetable. Some mushroom tissues fixed from 60 to 86 per cent. of their weight; beans, 17·2 per cent. —*C. R.*, April 30. C.

Book Notices.

Proceedings of the American Philosophical Society. No. 99, January to May, 1877.

Contains papers on the progress of the "North American Carboniferous Flora," now in preparation, L. Lesquereux; Tabular Synopsis of the Rhynchophora of America, J. L. Le Conte; Refraction Tables, A. K. Mansfield; E. S. Nettleton's first systematic collection of Oil Well Records in Venango County, J. F. Carll; Centres of Aggregation and Dissociation, P. E. Chase; Astrophyllite, Arfvedsonite and Zircon from El Paso, G. A. König; Measured Section of the Patleozoic Rocks of Central Pennsylvania, C. A. Ashburner; Coahuila, T. L. Kane; Continuation of Researches among the Batrachia of the Coal Measures of Ohio, a Dinosaurian from the Trias of Utah, and the Brain of Coryphodon, E. D. Cope; Composition of the Natural Gas from certain Oil Wells, S. P. Sadtler; Eight Meteoric Fireballs seen in the United States in 1876–7, and the Relative Ages of the Sun and certain of the Fixed Stars, D. Kirkwood; the Asserted Antagonisms between Nicotine and Strychnia, F. L. Haynes; a New Eurypteroid from the Coal Measures of Pennsylvania, C. E. Hall; the Timucua Language, A. S. Gatschet; Approaches to a Theory of the Cause of Magnetic Declination, and regarding some Mesozoic Ores, P. Frazer, Jr.; Experimental Tests of American Condensed Peat, J. B. Britton; Syllabus of Lectures on Sylviculture, J. T. Rothrock. C.

Proceedings of the Academy of Natural Sciences. Part I, for 1877.

Contains papers on Astrophyllite, Arfvedsonite and Zircon, G. A. König; Fertilization of Browallia elata, Asa Gray; Ibid., Thos. Meehan; Hudson River and Utica Slates of Pennsylvania, Anthracite from "Third-Hill Mountain," W. Va., Copper-bearing rocks of the Mesozoic Formation, and Contamination of Drinking Water, P. Frazer, Jr.; Contamination of Drinking Water, Eozoon, and The Diaphragm, J. Leidy, M. D.: Generic names proposed by Zittel, Stoliczke, and Zekeli, and Notes on Shells, T. A. Conrad; Unionidae of Ohio and Alabama, J. Lewis, M. D.; The Giraffe, H. C. Chapman, M. D.: The Habits of Quiscalus purpureus, J. Willcox; Excrementitious deposits found in the West, H. W. Henshaw; Fishes of Northern Ind., D. S. Jordan, M D.; Genera of North American Fresh-water Fishes, Id. and C. H. Gilbert; List of Plants recently collected on Ships' Ballast in the neighborhood of Philadelphia, I. Burk; The Valsei of the United States, M. C. Cooke; Influence of Nutrition on Fertilization, The Blue-bird and Holly Berries, Vitality of Seeds under low temperature, and Evolutionary Law as illustrated by Ab-

normal Growth in an Apple Tree, T. Meehan; Rocky Mountain Locusts, J. L. Le Comte, M. D.; Mineral Caoutchouc, G. C. Morris; Vital Power of Ants, Rev. H. C. McCook. C.

A PRACTICAL TREATISE ON LIGHTNING PROTECTION.—By Henry W. Spang. 12mo, pp. 180, with illustrations, cloth, $1.50. Claxton, Remsen & Haffelfinger. Philadelphia, 1877.

The author begins the work with an effort to instruct the reader upon the subject of electricity in its various phases, but more especially in its static condition, and as displayed in the phenomenon of thunderstorms. This occupies 68 pages, and while reasonably correct in its bearing on lightning protection, it contains some strange statements. For instance, on page 47, in speaking of electrical accumulations in the air and earth, he says: "In the earth it (the "electricity) is principally spread out over the subterranean water "bed" . . . While all will agree that moist earth is a much better conductor than dry, we know of no evidence that the electricity in the earth is localized.

Then follows a description of the various means employed for protection from lightning, including conductors, air and earth terminals, attachments to buildings, etc., in which the best methods are very clearly pointed out.

While several varieties of conductors, and methods of making good connections and attachments to buildings are approved, all of them are based upon the requirement that the conductors shall be of ample cross-section of metal, and that they shall terminate in a large metallic surface, planted in constantly moist ground.

Only on the subject of earth terminals does there seem to be any bias of judgment.

All the earth terminals *now* offered for sale by "Lightning Rod Men," are, without exception, condemned, but one devised by the author is pronounced pre-eminently effective, although having no more surface exposed, nor sunk deeper in the soil, than some others mentioned. This, together with the last seven pages, headed "Reform in the Lightning Protection Business," are certainly blemishes in an otherwise really useful book. K.

REPORT ON EUROPEAN SHIPS OF WAR, THEIR ARMAMENT, NAVAL ADMINISTRATION AND ECONOMY, MARINE CONSTRUCTION AND APPLIANCES, DOCK YARDS, ETC., ETC.—By John W. King, U. S. N., Washington, 1877. Gov't Printing Office.

Mr. King sailed from New York in August, 1875, under orders from the Secretary of the Navy, "for the purpose of personally observing and reporting upon recent construction and mechanical "appliances for ships of war." This report is the result of about

one year's study of this subject, and makes an 8vo volume of 273 pages and 29 illustrations, of armored ships, engines, guns, dock yards, etc.

Owing to the rapid strides made by the British Government in the last four years, in improving its own navy, and to the large number of war ships produced in England for other nations, that country proved to be the most fruitful field, and consequently we find 130 pages of the book devoted to the British War Vessels, while all other European navies are fairly noticed.

Mr. King finds that recently constructed war vessels of all classes are engined on the compound system, and reiterates the remarks made in his report as Chief of the Bureau of Steam Engineering, dated October 30th, 1871, that "there can be no hesitation in rec-"ommending that all cruising steamers of the navy, hereafter put "afloat, be engined on the compound system, and that all steam ma-"chinery, stored in the navy yards, that cannot be used to advantage "in old vessels, or converted into compound, be disposed of by public "sale, or broken up and used as old material."

Among other conclusions arrived at, Mr. King believes that, considering the fact that in the European navies the power of the guns and the weight and thickness of armor have continued to increase, it will result greatly to our advantage that we did not, after the civil war, go on building armored ships; that, had we done so, we should now have an antiquated armored fleet, while on the other hand "we "are now at liberty to take advantage of the results of the most "expensive and exhaustive experiments made by foreign powers, in "the construction of ships, of machinery of various kinds for naval "purposes, and in the manufacture of weapons."

Mr. King has drawn largely from the current engineering literature, government documents, etc., so that portions of the report are by no means new, but he has added much that is due to his personal investigation, and has arranged an amount of information in a systematic, compact form, such as has not hitherto been readily available. K.

Useful Information for Engineers, Boiler Makers and Firemen. By W. Barnett LeVan.

This little manual, compiled largely from works of standard authors, will be found very useful to owners and managers of steam boilers. Considerable space is given to the discussion of the proper strength and thickness of plates and tubes, and to the effects of the various operations upon these materials in the course of construction. It also contains rules and tables for determining the proper grate area, and area and length of chimney flues. To this is added much practical information derived from the author's own experience, which, together with the excellent statement as to the causes and prevention of explosions, will greatly aid in the economical and safe working of steam boilers. K.

DISCOVERY OF OXYGEN IN THE SUN BY PHOTOGRAPHY, AND A NEW THEORY OF THE SOLAR SPECTRUM.

By Prof. HENRY DRAPER, M. D.[1]

[Read before the American Philosophical Society, July 20th, 1877.]

I propose in this preliminary paper to indicate the means by which I have discovered Oxygen, and probably Nitrogen, in the Sun, and also to present a new view of the constitution of the Solar Spectrum.

Oxygen discloses itself by bright lines or bands in the Solar Spectrum, and does not give dark absorption lines like the metals. We must therefore change our theory of the Solar Spectrum, and no longer regard it merely as a continuous spectrum with certain rays absorbed by a layer of ignited metallic vapors, but as having also bright lines and bands superposed on the background of continuous spectrum. Such a conception not only opens the way to the discovery of others of the non-metals, sulphur, phosphorus, selenium, chlorine, bromine, iodine, fluorine, carbon, etc., but also may account for some of the so-called dark-lines, by regarding them as intervals between bright lines.

It must be distinctly understood that in speaking of the Solar Spectrum here, I do not mean the spectrum of any limited area upon the disc or margin of the Sun, but the spectrum of light upon the whole disc. I have not used an image of the Sun upon the slit of the spectroscope, but have employed the beam reflected from the flat mirror of the heliostat without any condenser.

In support of the above assertions the accompanying photograph of the Solar Spectrum with a comparison spectrum of air, and also with some of the lines of iron and aluminium, is introduced. The photograph itself is absolutely free from handwork or retouching. It is difficult to bring out in a single photograph the best points of these various substances, and I have therefore selected from the col-

[1] This paper has been pronounced, by able judges, to be the most important contribution to solar physics since Kirchhoff's great discovery. It is just thirty-five years since the author's father, Dr. John W. Draper, read his first paper on Activision, before the American Philosophical Society.

lection of original negatives that one which shows the Oxygen coincidences most plainly. There are so many variables among the conditions which conspire for the production of a spectrum, that many photographs must be taken to exhaust the best combinations. The pressure of the gas, the strength of the original current, the number of Leyden jars, the separation and nature of the terminals, the number of sparks per minute, and the duration of the interruption in each spark, are examples of these variables.

In the photograph the upper spectrum is that of the Sun, and above it are the wave-lengths of some of the lines to serve as reference numbers. The wave-lengths used in this paper have been taken partly from Angström and partly from my photograph of the diffraction spectrum published in 1872. The lower spectrum is that of the open air Leyden spark, the terminals being one of Iron and the other of Aluminium. I have photographed Oxygen, Nitrogen, Hydrogen and Carbonic Acid, as well as other gases, in Plücker's tubes, and also in an apparatus in which the pressure could be varied, but for the present illustration, the open air spark was, all things considered, best. By other arrangements the Nitrogen lines can readily be made as sharp as the Oxygen are here, and the Iron lines may be increased in number and distinctness. For the metals the electric arc gives the best photographic results, as Lockyer has so well shown, but as my object was only to prove by the Iron lines that the spectra had not shifted laterally past one another, those that are here shown at 4325. 4307. 4271. 4063. 4045. suffice. In the original collodion negative many more can be seen. Below the lower spectrum are the symbols for Oxygen, Nitrogen, Iron and Aluminium.

No close observation is needed to demonstrate to even the most casual observer that the Oxygen lines are found in the sun as bright lines, while the Iron lines have dark representatives. The bright Iron line at G (4307), on account of the intentional overlapping of the two spectra, can be seen passing up into the dark absorption line in the Sun. At the same time the quadruple Oxygen line between 4345 and 4350 coincides exactly with the bright group in the Solar Spectrum above. This Oxygen group alone is almost sufficient to prove the presence of Oxygen in the Sun, for not only does each of the four components have a representative in the Solar Spectrum, but the relative strength and the general aspect of the lines in each

case are similar. I do not think that in comparisons of the spectra of the elements and Sun, enough stress has been laid on the general appearance of lines apart from their mere position; in photographic representations this point is very prominent. The fine double line at 4319. 4317. is plainly represented in the Sun. Again there is a remarkable coincidence in the double line at 4190. 4184. The line at 4133 is very distinctly marked. The strongest Oxygen line is the triple one at 4076. 4072. 4069., and here again a fine coincidence is seen, though the air spectrum seems proportionately stronger than the solar. But it must be remembered that the Solar Spectrum has suffered from the transmission through our atmosphere, and this effect is plainest in the absorption at the ultra-violet and violet regions of the spectrum. From some experiments I made in the summer of 1873, it appeared that this local absorption is so great, when a maximum thickness of air intervenes, that the exposure necessary to obtain the ultra-violet spectrum at sunset was two hundred times as long as at midday. I was at that time seeking for atmospheric lines above H like those at the red end of the spectrum, but it turned out that the absorptive action at the more refrangible end is a progressive enfeebling as if a wedge of neutral tinted glass were being drawn lengthwise along the spectrum towards the less refrangible end.

I shall not attempt at this time to give a complete list of the Oxygen lines with their wave lengths accurately determined, and it will be noticed that some lines in the air spectrum which have bright analogues in the sun are not marked with the symbol of Oxygen. This is because there has not yet been an opportunity to make the necessary detailed comparisons. In order to be certain that a line belongs to Oxygen, I have compared, under various pressures, the spectra of Air, Oxygen, Nitrogen, Carbonic Acid, Carbureted Hydrogen, Hydrogen and Cyanogen. Where these gases were in Plücker's tubes a double series of photographs has been needed, one set taken with, and the other without, Leyden jars.

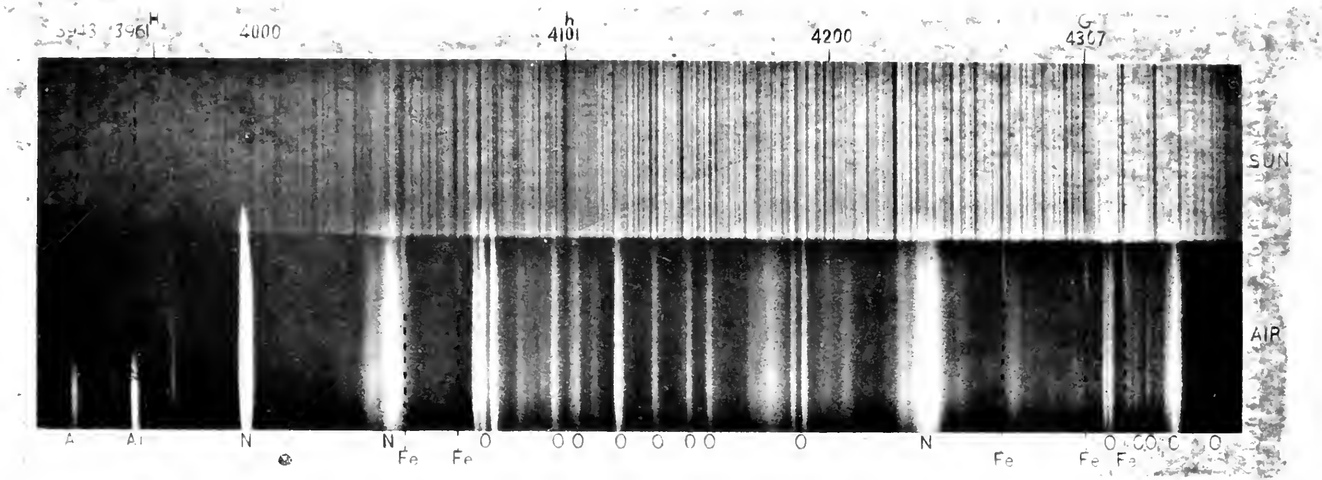
As to the spectrum of Nitrogen and the existence of this element in the sun, there is not yet certainty. Nevertheless, even by comparing the diffused Nitrogen lines of this particular photograph, in which Nitrogen has been sacrificed to get the best effect for Oygen, the character of the evidence appears. The triple band between 4240. 4227. if traced upward into the Sun has approximate repre-

sentatives. Again at 4041. the same thing is seen, the solar bright line being especially marked. In another photograph the heavy line at 3995., which in this picture is opposite an insufficiently exposed part of the Solar Spectrum, shows a comparison band in the Sun.

The reason I did not use air in an exhausted Plücker's tube for the production of a photograph to illustrate this paper, and thus get both Oxygen and Nitrogen lines well defined at the same time, was partly because a brighter light can be obtained with the open air spark on account of the stronger current that can be used. This permits the slit to be more closed and of course gives a sharper picture. Besides the open air spark enabled me to employ an iron terminal, and thus avoid any error arising from accidental displacement of the reference spectrum. In Plücker's tubes with a Leyden spark the Nitrogen lines are as plain as those of Oxygen here. As far as I have seen, Oxygen does not exhibit the change in the character of its lines that is so remarkable in Hydrogen under the influence of pressure as shown by Frankland and Lockyer.

The bright lines of Oxygen in the spectrum of the solar disc have not been hitherto perceived, probably from the fact that in eye observation bright lines on a less bright background do not make the impression on the mind that dark lines do. When attention is called to their presence they are readily enough seen, even without the aid of a reference spectrum. The photograph, however, brings them into a greater prominence. From purely theoretical considerations derived from terrestrial chemistry and the nebular hypothesis, the presence of Oxygen in the sun might have been strongly suspected, for this element is currently stated to form eight-ninths of the water of the globe, one-third of the crust of the earth, and one-fifth of the air, and should therefore probably be a large constituent of every member of the solar system. On the other hand the discovery of Oxygen and probably other non-metals in the Sun gives increased strength to the nebular hypothesis, because to many persons the absence of this important group has presented a considerable difficulty.

At first sight it seems rather difficult to believe that an ignited gas in the solar envelope should not be indicated by dark lines in the solar spectrum, and should appear not to act under the law "a gas when ignited absorbs rays of the same refrangibility as those it emits." But in fact the substances hitherto investigated in the sun are really metallic vapors, Hydrogen probably coming under that rule.



DISCOVERY OF OXYGEN IN THE SUN BY PHOTOGRAPHY, BY PROFESSOR HENRY DRAPER. M. D, 1876.

The upper part of the photograph is the spectrum of the Sun, the lower part is the spectrum of the Oxygen and Nitrogen of Air. The letters and figures on the margin are printed with type on the negative; with this exception the photograph is absolutely free from hand work or retouching. O. indicates Oxygen, N. Nitrogen, Fe. Iron, Al. Aluminium. The figures above the Sun's spectrum are wave-lengths; G. h, H., are prominent Solar lines at the violet end of the spectrum. The principal point to examine is the coincidence of the bright Oxygen lines with bright lines in the Solar spectrum. The picture is printed from Draper's original negative by Bierstadt's Albertype process.

The non-metals obviously may behave differently. It is easy to speculate on the causes of such behavior, and it may be suggested that the reason of the non-appearance of a dark line may be that the intensity of the light from a great thickness of ignited Oxygen overpowers the effect of the photosphere, just as if a person were to look at a candle flame through a yard thickness of ignited sodium vapor he would only see bright sodium lines, and no dark absorption lines. Of course, such an explanation would necessitate the hypothesis that ignited gases such as Oxygen give forth a relatively large proportion of the solar light. In the outburst of *T. Coronæ*, Huggins showed that Hydrogen could give bright lines on a background of spectrum analogous to that of the Sun.

However all that may be, I have no doubt of the existence of substances other than Oxygen in the Sun which are only indicated by bright lines. Attention may be called to the bright bands near G, from wave lengths 4307 to 4337, which are only partly accounted for by Oxygen. Farther investigation in the direction I have thus far pursued will lead to the discovery of other elements in the Sun, but it is not proper to conceal the principle on which such researches are to be conducted for the sake of personal advantage. It is also probable that this research may furnish the key to the enigma of the D_3 or Helium line, and the 1474 K or Corona line. The case of the D_3 line strengthens the argument in favor of the apparent exemption of certain substances from the common law of the relation of emission and absorption, for while there can be no doubt of the existence of an ignited gas in the chromosphere giving this line, there is no corresponding dark line in the spectrum of the solar disc.

In thus extending the number of elements found in the Sun, we also increase the field of inquiry as to the phenomena of dissociation and recomposition. Oxygen, especially from its relation to the metals, may readily form compounds in the upper regions of the solar atmosphere which can give banded or channeled spectra. This subject requires careful investigation. This diffused and reflected light of the outer corona could be caused by such bodies cooled below the self-luminous point.

This research has proved to be more tedious and difficult than would be supposed, because so many conditions must conspire to produce a good photograph. There must be a uniform prime moving engine of two horse-power, a dynamo-electric machine thoroughly adjusted, a

large Ruhmkorff coil with its Foucault break in the best order, a battery of Leyden jars carefully proportioned to the Plücker's tube in use, a heliostat, which of course involves clear sunshine, an optical train of slit, prisms, lenses and camera, well focussed, and, in addition to all this, a photographic laboratory in such complete condition that wet sensitive plates can be prepared which will bear an exposure of fifteen minutes and a prolonged development. It has been difficult to keep the Plücker's tubes in order; often before the first exposure of a tube was over, the tube was ruined by the strong Leyden sparks. Moreover, to procure tubes of known contents is troublesome. For example, my hydrogen tubes gave a spectrum photograph of fifteen lines, of which only three belonged to hydrogen. In order to be sure that none of these were new hydrogen lines, it was necessary to try tubes of various makers, to prepare pure hydrogen and employ that, to examine the spectrum of water, and finally to resort to comparison with the Sun.

The object in view in 1873, at the commencement of this research, was to secure the means of interpreting the photographs of the spectra of stars and other heavenly bodies, obtained with my 28-inch reflector. It soon appeared that the spectra of Nitrogen and other gases in Plücker's tubes could be photographed, and at first some pictures of Hydrogen, Carbonic Acid and Nitrogen were made, because these gases seemed to be of greatest astronomical importance on account of their relation to stars, nebulæ and comets. Before the subject of comparison spectra of the Sun was carefully examined, there was some confusion in the results, but by using Hydrogen the source of these errors was found out.

But in attempting to make a prolonged research in this direction, it soon appeared that it was essential to be able to control the electrical current with precision, both as to quantity and intensity, and, moreover, to have currents which when once adjusted would remain constant for hours together. These conditions are almost impossible to attain with any form of battery, but on the contrary are readily satisfied by dynamo-electric machines. Accordingly, I sought for a suitable dynamo-electric machine and motor to drive it, and after many delays procured a combination which is entirely satisfactory. I must here acknowledge my obligations for the successful issue of this search to Professor George F. Barker, who was the first person

in America to procure a Gramme machine. He was also the first to use a Brayton engine to drive a Gramme.

The dynamo-electric machine selected is one of Gramme's patent, made in Paris, and is a double light machine, that is it has two sets of brushes, and is wound with wire of such a size as to give a current of sufficient intensity for my purposes. It is nominally a 350 candle light machine, but the current varies in proportion to the rate of rotation, and I have also modified it by changing the interior connections. The machine can produce as a maximum a light equal to 500 standard candles, or by slowing the rotation of the bobbin the current may be made as feeble as that of the weakest battery. In practical use it is sometimes doing the work of more than 50 large Grove nitric acid cells, and sometimes the work of a single Smee.

The Gramme machine could not be used to work an induction coil when it first reached me, because when the whole current was sent through the Foucault interruptor of the Ruhmkorff coil, making 1000 breaks per minute, the electro-magnets of the Gramme did not become sufficiently magnetized to give an appreciable current. But by dividing the current so that one pair of the metallic brushes, which collect from the revolving bobbin, supplied the electro-magnets, the other pair could be used for exterior work, no matter whether interrupted or constant. The current obtained in this way from one pair of brushes when the Gramme bobbin is making 1200 revolutions per minute, is equal to 100 candles, and is greater in quantity than one would like to send through a valuable induction coil. I usually run the bobbin at 622 revolutions per minute, and this rate will readily give 1000 ten-inch sparks per minute, with the 18-inch coil. Of course a Plücker's tube lights up very vividly, and generally, in order to get the maximum effect, I arrange the current so that the aluminium terminals are on the point of melting. The glass, particularly in the capillary part, often gets so hot as to char paper.

As long as the Gramme bobbin is driven at a steady rate, the current seems to be perfectly constant, but variations of speed make marked differences in the current, and this is especially to be avoided when one is so near the limit of endurance of Plücker's tubes. A reliable and constant motor is therefore of prime importance for these purposes. A difference of 1 per cent. in the speed of the engine sometimes cannot be tolerated, and yet at another time, one must have the

power of increasing and diminishing the rate through wide limits. The only motor, among many I have examined and tried, that is perfectly satisfactory, is Brayton's Petroleum Ready Motor.

This remarkable and admirable engine acts like an instrument of precision. It can be started with a match, and comes to its regular speed in less than a minute; it preserves its rate entirely unchanged for hours together. Moreover, it is economical, cleanly, and not more noisy than a steam engine. The one of two-horse power I have, ran for six months, day and night, supplying water and air to the aquaria in the Centennial Exhibition at Philadelphia. At any time, on going into the laboratory, it can be started in a few seconds, even though it has not been running for days.

The Otheoscope.—In Crookes' radiometer, the warmed parts move, while the cooler parts commonly remain at rest. It seemed to the inventor of that ingenious instrument, that the best arrangement would be one in which the heated parts would be immovable, for it could be made of material best suited for the purpose, having sufficient extent of surface and the most favorable form, without regard to weight. The movable cold portion could be placed as near as possible to the warm, and it could be of such form, size and weight as would best utilize the effects produced. If the heated surfaces were of large dimensions, and made of silver, gold, copper, or other good heat-conductor, a very slight excitement of radiation would set up motion, and the blackened surfaces would act as if a molecular wind were escaping, normally to their plane. This wind easily puts in motion all the movable bodies that it meets, whatever may be their nature, color or form, acting at nearly every point like an ordinary wind. Such an instrument is called an otheoscope, from the Greek word *otheo*, to repel. Crookes exhibited several forms before the Royal Society at its meeting of April 25th, some of which worked in the open air, under the simple influence of solar light, without any receptacle for rarefied air. This new invention seems likely to enlarge, even more than the radiometer, our knowledge of the laws of molecular movements, movements which may be regarded as the key of the relations which exist between force and matter.—*C. R.*, May 14. C.

NOTES ON COMPENSATING-POWDER.

By Lieut. CHAS. A. L. TOTTEN, U. S. A.

[Continued from Vol. civ, page 63.]

Every theoretical consideration seems to support the argument in favor of the idea; is, then, its realization practicable? Unhesitatingly we answer in the affirmative. The consideration of this question opens several lines of investigation: the mechanical difficulties of manufacture, the chemical difficulties of combination, and finally the actual testing of the powder. To a certain extent, each of these points has already received the attention of the writer. In the present limited paper, however, it is only possible to glance at some of the more striking experiments that were instituted, and briefly study their inferences.

During the past year, at the Massachusetts Agricultural College, and with the assistance of Professor Gœssmann, the State Chemist, an exhaustive series of experiments was undertaken, with a view to determine the difference of the chemical action, if any, between the best American gunpowder, and English gun-cotton, when under various conditions and circumstances of mechanical combination. On the 1st of October, 1876, a number of jars were filled as follows: No. 1 contained Hazzard's best sporting powder, dry, and sealed. No. 2 contained the same as No. 1, but was left open to the air. No. 3 contained the same, but the contents were saturated with pure water. Nos. 4 and 5 were filled with gun-cotton, the one pulverized, the other in the disk form, and both dry. Nos. 6, 7 and 8 likewise contained gun-cotton, pure and in various forms, but saturated with pure water. The contents of all these jars were then carefully tested, and found to be absolutely devoid of free acid, or any other appreciable impurities. Jar No. 9 contained a quantity of dry cotton and powder thoroughly mixed. No. 10 was filled as No. 9, but the contents saturated with pure water. Nos. 11 and 12 contained dry powder and wet cotton. No. 13 contained dry cotton and wet powder. The contents of these jars were also carefully tested and found neutral to litmus, and true to their purport. Other jars, Nos. 14,—15, 16, 17, 18,—19, and 20, contained both substances mixed, and treated respectively with solutions of Ammonia, Nitric Acid, and Hydrochloric Acid: the Ammonia

to induce organic decomposition, the Nitric Acid because of its intimate relation to both substances, and Hydrochloric Acid for several chemical and accidental reasons. Besides the contents of the jars, several grains and cakes of compensating-powder, carefully made and in various conditions, were correspondingly treated. These jars and cakes were securely placed upon a glass-covered shelf outside the laboratory window, and left exposed to the alternate action of sun[1] and cold (freezing and thawing), for the space of nearly six months.

On the 23d of the following February they were again taken into the laboratory, and with Prof. Gœssmann's valuable aid, carefully re-examined and tested. The contents of jars Nos. 1 to 8 inclusive, containing the separated substances, were found to be unaltered. They were still neutral to fresh litmus paper; pieces of blue and red paper had in some cases remained unaltered side by side in the same jar during the entire period. Solutions of all of them were carefully filtered, and then treated with Barium-chloride as a test for sulphuric acid, a faint trace of which existed in the powder solutions, and was judged to be inherent in the sulphur, the latter being very retentive of this acid, and fresh powder giving the same reaction. The contents of jars Nos. 9 to 13 inclusive, were likewise found unaltered. This was the crucial part of the chemical investigation, for in this set of jars the two substances were mixed, and under conditions as disadvantageous to constancy as could fairly have been required. They were still neutral to litmus, gave the same clouds in the Barium-chloride test, obviously for the same reason, and when further specially tested for nitric acid, by the indigo and heat reaction, showed conclusively it was not present. In jar No. 14, ammonia was still present, the solution responded to the Barium-chloride test, and a few drops upon platinum left, when evaporated over an alcohol flame, faint traces of ammoniacal compounds—evidently the result of a decomposition induced by the ammonia. In jars Nos. 15, 16, 17, and 18, litmus paper showed that acid was still present, and the indigo test proved it to be nitric acid, as was naturally to be expected. This acid had to some extent acted destructively upon the substances, as proved by evaporation over an alcohol flame, and the solution still precipitated a cloud from Barium-chloride. Jars Nos. 19 and 20, which had been treated with the Hydrochloric acid, gave similar results to the tests.

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[1] Sometimes erroneously supposed to *induce* spontaneous action.

The cakes corresponding to the various jars acted in a respectively similar manner. Of course in the various cases where powder had been moistened there was an efflorescence of its nitre (the powder was mechanically ruined), but in all cases only the chemical actions were noted. Samples of these substances, as they came from the tests, were dried, and found to be still explosive.

From these severe experiments it is fair to conclude, that under all the ordinary circumstances of exposure, to which an explosive used for artillery purposes is liable to be subjected, this form of compensating-powder will undergo no chemical change attributable to the mutual action of gunpowder and gun-cotton—*in other words, it will preserve its virtue as reliably as either of the constituents.*

While awaiting the result of these chemical experiments, two other series were instituted, one with a view to examine the mechanical difficulties of the manufacture of compensating-powder, and the other to determine its action. Of course they were crude, for both of the investigations were attended with most serious drawbacks, owing to the almost entire lack of proper facilities, and therefore every allowance must be made where they do not fully justify theoretical expectations. These experiments were likewise carried on in the Military Department of the State College, and in them considerable assistance was lent by several members of the Senior class, especially by Cadet J. K. Mills, of Missouri.

The first cakes made were cubical, two inches on an edge, the interior core being cylindrical, one inch high and one inch in diameter. This size and form for the outer case were chosen because they very nearly approached those of the powder grains used in the 81-ton gun.[1] The form of the interior core was simply an adaptation to circumstances; the cotton had been kindly donated by Capt. Breese of the Torpedo Station, and that employed in these cakes was already in this form, it being the best imported Abel disk.

Several cakes were successfully made of this size and shape, but it was soon necessary to abandon the attempt because the press and dies were of wood, and though carefully made and shellac-polished, swelled

[1] The powder used in the 81-ton gun is understood to be cubical and 1·75 inches on an edge. This suggested the size for the first grains of compensating-powder, but the dimensions were taken somewhat larger so as to reduce still more the first strain upon the gun, and also give the core as great a capacity as possible, for convenience in manufacture.

badly and delayed the work; also the pressure needed for so large a grain was too great for the only machine at hand, merely a large-sized joiner's clamp.

A steel press with dies was then procured from the Holyoke machine company. It was capable of making spherical grains one inch in diameter, with spherical cores of half an inch diameter. It worked admirably, and with it quite a number of grains were manufactured and their characteristics studied. We shall not detail these, nor refer minutely to the difficulties which offered themselves, and the means that were taken or suggested to overcome them. The experiments showed, however, that the powder was entirely practicable as a mechanical possibility, and suggested several ways to carry on its manufacture so as to satisfy the demands of a war footing. It may be remarked here, in passing, that wherever utility makes a necessity, invention will find the means, and that the same demand which makes an envelope-machine cheap and valuable at $30,000, will not hesitate at the simple devices necessary to produce this powder.

Of course the decisive test in a programme of such experiments is to *fire* the powder in heavy guns and with full working charges. We certainly have the *power* if we can only *harness* it, and the idea seems to be so very near to what is desirable, *that its accomplishment must be possible.*

It once puzzled a king of England to know how an apple was introduced into a dumpling. It was simply an old housewife's secret, yet 'tis said the royal family experimented weeks at dumpling manufacture, to the amusement of the realm.—"*The proof is in the eating,*" *and it was the good eating of the dumpling that made the secret of its construction worth finding out.* But the main proof of this powder is in the firing; if this bears out the premises of theory, then the secret of its manufacture will be well worth our study, even if Uncle Sam himself has to soil his fingers with the dough.

From what has gone before it will be gathered that the name *compensating*, by which we distinguish this powder, is derived from two considerations: first, the grain is *built up* in such a manner that an interior core of higher explosive quality shall *compensate* for what would be wasted in a homogeneous powder charge; second, the explosion of this interior core is expected to fill up the increasing space

in rear of the projectile—in other words, to *compensate* for the diminished intensity of the powder-gas due to this increase.[e]

From the theory of its construction it is intended that every pound of it shall be an *efficient* pound. In compensating a hundred-pound powder charge, for its waste of 60 pounds, we may pursue one of several methods; three of these are worthy of present notice.

Fifteen pounds of gun-cotton are equivalent to at least 60 of powder. We may introduce this cotton at its maximum density, as a core into the 40 working pounds of powder. But if the powder, too, be kept at its maximum density, then, since we have the same number of spheres, but only 55 pounds against the original 100, the resulting spheres would be too small, hence the density of the powder must be reduced so that the size of the sphere may be kept constant.

A second method would be to mechanically adulterate the 15 pounds of gun-cotton with 45 pounds of *ordinary* cotton; we *might* then get a core the equivalent in power, and occupying the original space, of the 60 pounds of powder; surrounding this with the 40 working pounds of powder, at its maximum density, our resulting spheres would be of proper size and density, and to some extent compensated. The third expedient is to load the 40 pounds of powder with their full capacity—60 pounds—of gun-cotton. This would be distributed through about 1800 spheres and would have the force of some 280 effective pounds of powder. To obtain such a power from powder alone we would have to employ some 700 pounds—an amount that would more than half fill the 15-inch gun, and be as apt to burst it from its wadding action as from its ungovernable force.

Any of those methods may succeed, and all of them are worthy of trial, especially the latter. From some study, however, of the many bearings of the question, we are inclined to favor the first one, in a more or less modified form, as perhaps the most feasible. On the foregoing figure (JOURNAL OF THE FRANKLIN INSTITUTE, vol. civ, page 61) we have indicated the size capacity of a grain built up

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[e] This idea may be expressed in a formula which shall apply to the granular construction of compensating-powder out of any two or more explosive substances, or out of the same substance in different conditions. Separate equations, for each case, may give the relative amounts of the various explosives required to compensate for waste, lack of force, increased space, etc., etc. The results, given by these formulæ, will depend upon the explosive force assigned to each constituent layer of the grain, and conversely to realize any required result, we must employ an explosive whose absolute force corresponds to it, as determined by calculation.

according to the requirements of this method. The one-half inch core of each sphere contains 58·3 grains of cotton at a considerable density; the jacket contains only 155·5 grains of powder; its density is therefore reduced, but its thickness and rate of combustion correspondingly increased. 55 pounds of this powder are spread through 1800 spheres, contain 40 efficient pounds of powder and 15 of gun-cotton, and occupy about the same space as a hundred-pound powder charge in the spherical form.

Let us estimate the force-capacity of a hundred-pound charge of this powder. It would contain some 27·2 pounds of gun-cotton and about 72·7 pounds of powder, which would be distributed through some 3272 spheres.[i] 27·2 pounds of cotton are equal to at least four times that amount of powder, or 108·8 pounds, which, added to the effective pounds of the powder-jacket, gives us an equivalent of 181·5 effective pounds of gunpowder. To obtain this amount from powder alone we would have to employ 453·75 pounds.[ii] Comparing, then, a hundred-pound charge of compensator with one of hexagonal powder, we notice that from the former we gain 181·5 effective pounds, while from the latter we obtain but 40; a difference of 141·5 effective pounds in favor of the change, and the whole of which, let it be remembered, is to be expended *after the* 72 7-*pound powder-jacket* has done its best work upon the initial velocity. These figures are certainly startling, but let us examine the subject from another standpoint, and determine how much compensating-powder must be used to obtain the same effect that we now derive from the hundred-pound service-charge of the 15-inch gun. In other words, how much compensating-powder is required to equal 40 *efficient* pounds of powder.

Every 3·66 pounds of compensating-powder contain 2·66 pounds of powder and one pound of cotton; but the pound of cotton is equal to at least four pounds of powder; 6·66 is therefore the powder equivalency of 3·66 pounds of compensator. Dividing 40 by 6·66, we obtain 6, as the number of pounds of gun-cotton, and multiplying 6 by 2·66, we find 15·96, as the powder required to cover it. This gives 21·96, say 22 pounds, as the required amount: figures not perhaps so startling, but certainly as noticeable. This charge would contain only 719·8 spheres, would occupy but little more than one-

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[i] The hundred-pound service-charge of Hexagonal powder contains from 8000 to 7200 distinct granules, and occupies a calibre's length, more or less, when in the 15-inch gun.

[ii] See foot-note, Jour. Frank. Inst., civ. 63.

third the space of the present powder charge (both in the bore and *magazine*), would possess all its force, none of its waste, and be an *accelerator.*

It will not be excessively expensive to manufacture. It is considered that gun-cotton, made on a large scale, will be as cheap, if not cheaper, than powder, weight for weight; therefore all the extra expense may be charged to the grain construction.[1] The Government finds powder necessary at 25 cents a pound, even though the waste is over 60 pounds in every 100. It certainly cannot cost 25 dollars to manufacture 22 pounds of compensating-powder, and as 15·5 dollars of every 25 that we now spend for powder are a dead loss, we have an ample margin in which to make the venture worth trying. In this important sense, also, the powder may prove to be "*compensating.*"

It will, perhaps, repay us to examine this proposed combination, and its constituent parts, under their chemical symbols.

The theoretical burning of gunpowder is expressed by the following equation:

$$2\,NO_3K + 3\,C + S = 3\,CO_2 + 2\,N + S\,K_2 \ldots\ldots\ldots\ldots (A).$$

The explosion of gun-cotton is given by the formula:

$$2\,C_6H_7(NO_2)_3O_5 = 3\,CO_2 + 9\,CO + 6\,N + 7\,OH_2 \ldots\ldots\ldots (B).$$

In the explosion of compensating-powder, the element *succession* is most noticeable. This is favorable to the stability of the several gases of its constituents when *brought together* under such peculiar conditions. The similar nature of the products of combustion of gunpowder and gun-cotton, seems to preclude any tendency (which very *dissimilar* gases might have) to result differently in combination than they do when separated. Hence we may simply combine these two reactions by addition, and obtain a legitimate expression for the explosion of compensating-powder, namely:

$$[2NO_3K+3C+S]+[2C_6H_7(NO_2)_3O_5]=(3CO_2+3CO_2)+9CO+(2N+6N)+7OH_2+SK_2=6CO_2+9CO+8N+7OH_2+SK_2 \ldots\ldots (C).$$

It is barely possible that the water in this reaction may be turned to account for the oxidation of the sulphide. But in this case *hydrogen,*

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1 "Supposing quantities which would produce equal effects, then its cost (gun-cotton) is considerably less than that of gunpowder. Under ordinary circumstances, at a normal price for cotton, the cost of manufacture of gun-cotton is under fourteen pence per pound."—Baron Lenk before British Commission.—*Holley.*

a still more elastic gas, would be freed, and take the place of the steam. Such a variation would result in greater chemical action and therefore in the production of a higher temperature, all of which would finally be appreciated in ballistics as an accelerator.[f]

Comparing these reactions critically, we may obtain a very clear idea of the gas-capacity, and character, of the powder that will result from the combination proposed. It must be recalled in this comparison, that while the powder gases result from a progressive *combination* of its elements, those of the detonator come from its almost instantaneous *disintegration.* It is also to be noticed that the volume of the latter gases is many times greater than that of the former, and from the large amount of water it contains, that it has all the elasticity of steam.

It is claimed that gunpowder itself acts as an accelerator, from the fact that the great heat of its confined explosion must expedite the change into gas of its interior layers—just as a coal fire burns better and better until it reaches its maximum. This is obviously the case, though it is not an appreciable argument when offered against a combination that *is* a noticeable accelerator. This very feature, however, will work in favor of the compensating construction, for the accelerated burning of the powder-jacket will only be of importance during a very brief period, until the grain has become relatively small—beyond this point it is valueless; but the interior core, exploding at this same moment, will take up and carry to its climax this action, so well begun.[g]

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[f] From the mechanical nature of gunpowder we may vary its gaseous products to almost any extent, a feature which may perhaps be advantageously employed in the compensating construction.

Gun-cotton does not contain sufficient oxygen for the complete combustion of its carbon; this is shown by formula (B), where, though we find nine atoms of CO, we have only three of CO_2 To remedy this deficiency, some advantage might be gained by increasing the amount of nitre used in the powder jacket. *An excess* of oxygen in the powder products might thus be *made* to furnish sufficient to complete the *oxidation* of the interior core. Attempts, more or less successful, have already been made to nitrate or chlorate gun-cotton, with a view to supply this deficiency. The process is to soak the substance in saturated solutions of nitrates or chlorates.

[g] Commander Marvin, U. S. Navy, in his printed lecture on Granulations of Gunpowder, sums up the influences which determine the rate of consumption of powder grains as six in number.

1st. The purity of ingredients.

2d. The thoroughness of incorporation.

The experiments that were conducted to test the explosive action of the proposed combination, were the least comprehensive of the series. In so far, however, as could reasonably have been expected, they gave as satisfactory results as the others. No large guns were available for experiment, and so it was simply attempted to establish the fact that the combination would result as predicted. This was attended with considerable difficulty, as the only guns at hand were Springfield rifles.[1] It was utterly out of the question to try regular compensating-powder in these, and so resort was had to the following expedient.

A number of metallic-cases were carefully loaded as follows: Nos. 1 to 6 inclusive, contained the regulation charge of 60 grains of gunpowder; Nos. 7 to 9 inclusive, contained 20 grains of gun-cotton; Nos. 10 to 12 were loaded with 30 grains of powder and 10 grains of cotton each. Estimating gun-cotton at three times the force of gunpowder, Nos. 1 to 12 inclusive were severally equivalent to one

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3d. The specific gravity.

4th. The volume of the granule.

5th. The extent and *character* of the surface at the *initial, intermediate*, and *final* periods.

6th. The pressure under which combustion takes place.

So far as the first four and the last of these conditions are concerned, they may or may not be different in the case of compensating-powder, from what they are in that of hexagonal. Probably they will be the same, as the grain is to all intents and purposes *a powder grain during its first instants of combustion.* In the 5th condition, however, circumstances will have been considerably changed. This is the condition which specially concerns all compositions that pretend to be accelerative in their action. Examining the compensator in the light of this 5th consideration, we have in the initial period a large-grained charge of powder beginning its combustion, in the intermediate stage we find this powder combustion self-accelerating, and in the final one we have a charge of gun-cotton (more than equivalent to the powder already burned) detonating.

Just as we go to press, Ordnance Notes, No. 63 (on the 100-ton gun), reaches us. From page 1 we quote: "We may now add that the Italians have a powder of their own devising, called '*Progressive Powder.*' This is made in cubes, but the centre is less dense than the exterior so as to allow a more rapid combustion, as the cube burns away toward the centre." A snow-ball, from the very way in which it is made, is less dense on the interior than on the exterior; perhaps this—mere utilization of natural results—is the secret of manufacture of the Italian powder. Their idea is certainly good, but an old one in this country. We are ready now for an advancement in cannon powder. "All along the line" they seem to agree with us that we must have a "*compensating-powder*"—the only matters appears to be, *how* to make it.

[1] Cadet Model, Cal. ·50

of 60 grains of gunpowder, and theoretically were expected to accomplish the same work. Nos. 13 to 17 inclusive, were each loaded with 30 grains of powder, and amounts of cotton which ranged regularly up from 12 to 20 grains, the common difference in the progression being 2 grains. The powder equivalents of these charges were respectively 66, 72, 78, 84 and 90 grains. Finally, Nos. 19 and 20 contained 20 grains of powder and 20 of cotton each. Other shells were loaded with 30 grains of powder only, and still another set contained amounts of gun-cotton alone in charges of 2, 4, 6, 8 and 10 grains. A bullet weighing 550 grains was used with each charge, and in all the cases where powder and cotton were used in combination, save Nos. 19 and 20, the contents of the shell were arranged as follows: The powder was first introduced and pressed carefully home, the gun-cotton was then introduced as a wad, and to delay its ignition until the bullet should be moved, it was securely sealed in two thicknesses of thin oiled paper. In cases Nos. 19 and 20 no paper was used, but the cotton simply wadded down upon the powder. As no velocimeter was obtainable, the initial energy in the several cases had to be judged of from the penetration of the bullet. With a view to facilitate this, the target consisted of a strong box filled with pieces of inch plank placed in vertical juxtaposition against its ends. These were arranged so as to be easily withdrawn after each fire, for the purpose of tracing the course of the bullet. The rifle was secured to a wooden horse, was placed ten feet from the target, was discharged by means of a lanyard, and was carefully cleaned and oiled after each discharge.

The firings took place in the order of their numbers, and the first six gave a general and average penetration of 12 inches. At the 7th fire the rifle burst at the chamber, blowing the breech and stock to pieces, and driving a "*tumbling*" bullet through 13 inches of plank. Cartridges 8 and 9 were not fired for fear that they would result as No. 7 had. A new gun was put in place, and Nos. 10, 11 and 12 gave an average penetration of 14 inches. Nos. 13 to 17 (3 of each) gave a generally increasing penetration, varying from 13 to 20 inches. Under the action of No. 19, the second gun burst similarly to the first, although with more wreck, and the bullet lodged in the 9th plank. No. 20 was not fired. 30 grains of powder alone gave a penetration of 8 inches, and 2, 4, 6 and 8 grains of gun-cotton gave respectively 1, 3, 6 and 8 inches penetration.

Examining the results of the first 12 fires, we see that they agreed quite closely with calculations. The bursting of the first gun under charge No. 7 was rather expected, from the very nature of the charge, though its excellent penetration, under the circumstances, was somewhat of a surprise, and as an argument on the relative force of powder and cotton favors a higher estimate than 3 for the latter. The action of charges 10, 11 and 12 is regarded as a strong argument in favor of the compensating principle—they gave more than the requisite penetration, and since each contained but 30 grains of powder (and 10 of gun-cotton), the additional work (6 inches) must have been accomplished by the gun-cotton.[h] Charges Nos. 13 to 17 endorse this conclusion. The bursting of the second gun, under charge No. 19, was also natural. This charge was even greater than that of No. 7, and the lack of the oiled cover about the cotton must have caused the ignition of the two explosives at practically the same instant.

Other experiments and examinations were conducted with reference to these substances, and their combination, but they are minor to

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[h] The idea of starting a projectile by means of a charge of powder, and accelerating its velocity with gun-cotton or some other higher explosive, is by no means claimed to be new. Mechanical mixtures of powder and other explosives have been attempted, but have generally failed. In the explosion of such compounds, the more sensitive ingredient, especially if it be a detonator, is used up before the other has an opportunity to develop its energy, or else the weaker is lost in the more powerful action of the stronger. In a mere mixture the weaker substance may be said simply to adulterate the stronger.

A device was brought out some years ago in England, which consisted of a case containing powder surrounding a shorter interior one, of less diameter, filled with gun-cotton. A projectile, shouldered so that its base went a certain distance into the larger case, had a sub-calibre projection which penetrated for some distance further into the interior one. The action was to start the projectile with the powder gas; it was thus forced to take up sufficient motion to overcome inertia before its "tang" could leave the interior case, and the gun-cotton explode for purposes of acceleration. This contrivance was intended only for use in small arms, but while its test warranted the expense of patenting the complications in the manufacture, the small demand for the improvement in this form led to its abandonment for general purposes. We mention it here, as it bears directly upon the point which our third series of experiments goes to establish—namely, *that gun-cotton will accelerate the motion of a projectile which gunpowder has started.*

It is clear, too, that the method of combination which is proposed in the regular compensating grain is essentially different from this British attempt in the same direction. In the compensator, the powder itself is a jacket (or case) sufficiently strong and durable, certainly less expensive, and far more simple, than those just noticed.

these given above, and as our paper has already exceeded convenient length, we cannot notice them at present.

There are evidently many other explosive combinations, that offer fields of investigation as interesting as these that we have just studied. It may, perhaps, be found that some one of the Picrates, which are somewhat similar, in nature and composition, to gunpowder, but several times stronger, will act as a core in a compensating-cake, even better than gun-cotton. Or it may be found practicable to form charges for heavy guns out of a number of large, hollow grains, or out of boxes, so to speak, made of press-cake powder, and filled with fine-grained rifle powder. There would be no chemical objection to such a combination as the latter; it would certainly burn upon the accelerating principle, and would be mechanically possible; moreover it might be calculated with a view to eliminate powder waste.

Of course the experiments that we have sketched are not exhaustive, but they surely lend interest to the study of explosives. From the very nature, however, of such a subject, it is clear that vast means, delicate instruments, and special students, are necessary, to carry to their legitimate ends experiments of so much importance. Such facilities are possessed only by governments, and as the matter is of special value only for war purposes, it will undoubtedly enlist their attention.

The best guns of our day are "built up;" they are expensive, but certainly practical monuments to theory. Again, we study the circumstances of impact, and of trajectory motion, with a view to perfecting already elaborately made projectiles—"built up" projectiles. Why, then, should we not study the *motor-power* also from this same fruitful standpoint?

We may reasonably doubt that modern military science has no motor for the monster projectile more capable than gunpowder. It is one thing to assume this as the positive starting point of ballistics, but it is quite another, and not, perhaps, too radical a one, to approach this topic scientifically, and make *true* theory "build up" the agent that modern artillery demands.

We have practically perfected gunpowder, but the last great step in artillery—the great guns now on trial, the greater ones in prospect—requires a corresponding advance in explosives, a step which must consequently be taken in some new direction.

The near perfection of telegraphy did not prevent the possibility of the telephone, and if the latter redeems its promises, this instrument must supplant its worthy predecessor. The change from our present forms of gunpowder to a compensating-powder, would be similar to that from the telegraph to the telephone. In both cases improvement is the logical result of a similar line of study; in both of them we profit by experience, by the demands of necessity, and by the possibilities of mechanism. In neither do we discard the valuable and essential features of their predecessors, or make so radical a change as to render valueless our stock on hand.

Anæsthesia of Plants.—The vapors of chloroform paralyze the sensitive plant, in whatever position they find it, with the leaflets open or closed. M. P. Bert has found that chloroform or ether destroys the irritability without affecting the spontaneous movements. The result is the same when the plant is placed for some time in absolute darkness, while a continued light increases the irritability, and destroys the spontaneous movements. According to Pfeffer, the medial leaflets of a sensitive leaf may be paralyzed by an anæsthetic, without hindering the passage of irritation from the terminal leaflets to the base of the leaf, and thence to the neighboring leaves. M. Heckel has observed the action of anæsthetics on the stamens of barberries. He reports having produced a manifest sleep in branches plunged into 40 grains of water to which 3 grains of chloroform had been added, while chloral hydrate would not act unless it was changed into chloroform by the action of soda. But in this plant the anæsthesia occurs only in the position of repose. If the vapors of chloroform find the stamens raised against the pistil, they fall gently, and when they rest on the petals they are found to be asleep; irritations are without effect until this lethargic sleep is over. It is well known that ether and chloroform temporarily destroy the movements of protoplasm and of vibratile cilia. M. Mussat has described the contraction of the cellular plasmode, upon contact with chloral hydrate. Heckel has greatly lengthened the chloroform sleep of the barberry flower by introducing a drop of a concentrated aqueous solution of chlorhydrate of morphine.—*Les Mondes; Morren, Acad. roy. de Belgique.* C.

AN ECONOMICAL FORM OF GASHOLDER FOR THE LIME-LIGHT.

In the summer of 1875 the Franklin Institute determined to put in a pair of holders of considerable capacity for oxygen and hydrogen, so as to avoid the necessity of preparing the gases on each occasion that they were to be used, and other inconveniences in the use of bags and press-boards in connection with the lime-light. As it was desirable to use as great economy as was consistent with effectiveness and durability, the design shown in the accompanying illustration was adopted as covering these points.

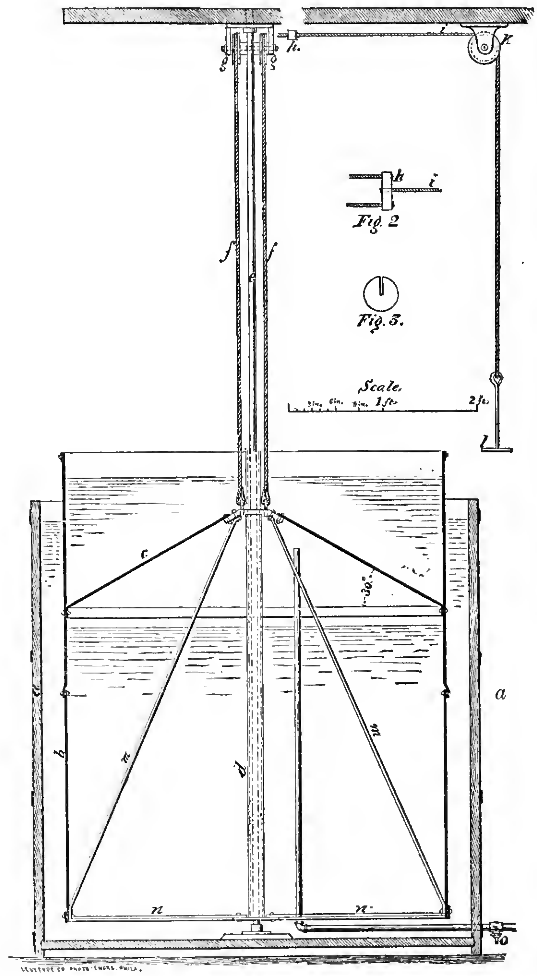

Fig. 1.

Fig. 1 is a sectional and Fig. 4 a perspective view. *A* represents a wooden tank or tub, $4\frac{1}{2}$ feet in diameter, and 5 feet high, made of cedar wood, and hooped with iron in the usual manner; *b* represents the holder, made of No. 10 galvanized iron, and is 4 feet diameter by 5 feet high. The roof or top *c* is conical in shape, rising on each side at an angle of about 30°, and is attached to the sides of the holder 18 inches below the top edge, thus forming a receptacle for

water to act as a weight to produce the required pressure when the gas is being used.

In the centre of the holder, and extending its extreme height, is placed the tube *d*, passing through and fastened by a water- and gas-tight joint to the roof *c*, and being held firmly in the centre at its lower end by the four braces *n*. The holder is given additional stiffness by the diagonal braces *m*, which, however, may be dispensed with in holders of this size or smaller. From the centre of the bottom of the wooden tank, rises a bar or post of 1 in. round iron, passing through the tube *d*, and reaching to the ceiling of the room, thus forming a simple and almost frictionless guide for the holder in its vertical movements.

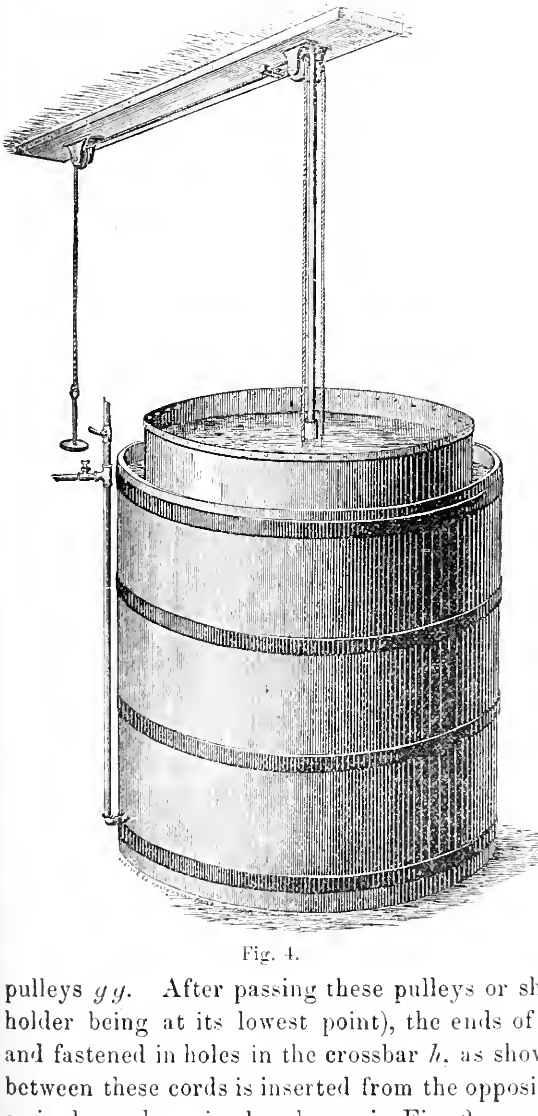

Fig. 4.

On either side of the tube *d*, and as near as convenient, are placed two eye-bolts, from which are carried wire cords *ff*, up to and over the pulleys *gg*. After passing these pulleys or shrives a few inches (the holder being at its lowest point), the ends of the cords are inserted and fastened in holes in the crossbar *h*, as shown in Fig. 2. Midway between these cords is inserted from the opposite side of the crossbar, a single cord, as is also shown in Fig. 2, as well as in Fig. 4, which

represents this portion broken off and swinging around at a right angle to its proper position. This cord *i* passes over the shrive *k*, and extends down to within a convenient distance of the floor, and has attached to its extremity the pan *l*, for holding the weight shown in Fig. 3. Care must be taken that the distance of the shrive *k*, from the cross-bar *h*, and also from the bottom of the scale pan to the floor, is as great as the proposed rise and fall of the holder. The arrangement of cords, shrives, etc., will be readily seen in the perspective view, Fig. 4.

The pipe for the admission and exit of the gas, is shown as passing through the side of the wooden tank, and rising near the centre to within a few inches of the top of the holder.

The manner of using is as follows: The cock *o*, in the inlet pipe, being open to the atmosphere, water is admitted to the tank until it rises to the top of the pipe. Weights (Fig. 3) are placed on scale pan *l*, in sufficient amount to overbalance the weight of the holder, and to overcome the friction of the cords and pulleys, when the cock *o* should be closed. Communication being opened between the inlet pipe and the source of gas supply, the gas enters, and the holder rises until filled. The supply of gas should then be cut off, the weights removed from the pan *l*, the space at the top of holder filled with water, and the gas is ready for use, under the necessary pressure. When the holder is exhausted, the water on top is run off by means of an india-rubber tube, acting as a siphon, the weights replaced on the pan, and the holder is ready for refilling.

Where the oxy-hydrogen light is much used, holders are almost indispensable, and in all cases they effect a large saving of time and material in the preparation and use of the gases. K.

Sun-Spots and Magnetism.—Prof. Wolf finds, by applying his formula for the relation between sun-spots and magnetism, a calculated value of 6·40′ for the mean variation of declination at Prague. The observed value was 6·47′, an agreement which he justly regards as marvelous. He believes the mean sun-spot period to be $11\frac{1}{9}$ years, but there are strong indications of a grand period of 178 years, embracing 16 solar periods of $11\frac{1}{9}$ years, and 15 revolutions of Jupiter. *Les Mondes*, April 5. C.

TESTS OF STATIONARY STEAM BOILERS AT THE CENTENNIAL.

The report of Mr. E. M. Hugentobler, expert in charge of the steam boiler tests at the Centennial, to Mr. John S. Albert, Chief of the Bureau of Machinery, is now going through the press, and will cover about 200 octavo pages. It contains all the logs or records of observation, taken with much detail, and otherwise bears evidence of much painstaking in making the tests.

Through the courtesy of Mr. Albert, we have been furnished with a copy of the proof-sheets of the report, from which the following is an extract.

The tables on pages 108 and 109, containing some of the more important results, are compiled from more extended tables, of which there is a separate one for each boiler. In these latter there is also a column of the results of the "Capacity Test" of each boiler, but as the "Economy Test" is of more value to the steam user, only the last need be given here. K.

Fourteen boilers were tested in the order named: the Wiegand, the Harrison, the Firmenich, the Rogers & Black, the Andrews, the Root, the Kelly, the Exeter, the Lowe, the Babcock & Wilcox, the Smith, the Galloway, the Anderson, and the Pierce boilers.

NATURE OF THE TESTS.

Two tests, each of eight hours' duration, were made of each boiler; the first with full natural draft and clean fires to determine the potential evaporation, the second with fires regulated to burn about three-fourths as much coal as before, or, in other words, to approximate average working conditions with a view of ascertaining the economical evaporation.

Calorimeter observations of the quality of the steam were taken at stated intervals during all the tests, and have been taken into account in computing the results of the several trials.

During all the trials a steam-pressure of seventy pounds was regularly maintained on the boilers by adjusting the stop-valves; a steam-gauge was attached on the steam-pipe just below the stop-valve, and a man was stationed at all times on top of the boiler to watch the gauge and regulate the valve accordingly.

Before beginning an experiment, steam was raised to seventy pounds, when the stop-valve was closed, fires hauled, and ash-pits cleaned. As soon as new fires could be established with weighed wood and coal, the water-level was noted (with fire-doors closed and fires burning), after which the stop-valve was opened; the time of opening the valve being recorded as the time of starting the test. After steaming for eight hours the stop-valve was closed and the water-level again noted (with fire-doors closed); the fires were then hauled and extinguished, and the ash-pits cleaned out.

All the coal and kindling wood, estimated at its equivalent in coal, consumed for starting and maintaining new fires, were charged to the boiler, and all the water pumped into the boiler to maintain the level at the same height was credited to the boiler as evaporated, subject to corrections indicated by calorimeter, as explained below.

In the two tests of the Kelly boiler, the economy trial of the Exeter, and the economy trial of the Babcock & Wilcox boilers, the level at stopping was higher than at starting; and for those tests the amounts of water corresponding to the differences in level have been deducted from the amounts pumped into those boilers. In all other cases, however, the level at stopping was the same as at starting, or when lower a few strokes of the pump would bring it up to the required point, the water thus pumped being of course credited to the boiler as having been evaporated.

In all cases precautions were taken to trace all connections to the boiler on trial, to see that they were tight; and all blow-off pipes were disconnected, so as to detect any leak that might occur through the blow-off valves. In two or three instances slight leaks occurred, but all the water was collected and deducted from the amount fed into the boiler.

Before starting, the approximate amount of coal needed for the trial was weighed out of the coal-bin and dumped in a separate pile on the floor, away from all other coals. From this pile coal was taken in barrows as required for running the test, and the weight of each barrow-load noted. This plan of keeping two separate accounts of the coal removed all chance of error in the amount of coal actually consumed, as at the close of each experiment the two accounts were balanced, and any error would have been detected at once. The second coal account has been taken as the basis for calculating the evaporation, adding to it, of course, the equivalent of the kindling

wood, which was taken at the rate of 0·40 pound of coal per pound of wood.

Upon completing a trial, fires were hauled and extinguished as rapidly as possible, the grates and ash-pits carefully cleaned, and all the coal, ashes and clinkers hauled from under the boiler were sifted. The coal was carefully picked by hand and weighed separately. This amount of coal deducted from the amount of coal fired on the grates gives the amount of coal actually consumed. By deducting from the latter the amount of refuse (ashes and clinkers), the amount of combustible consumed was determined.

The feed-water measuring apparatus consisted of two metallic tanks placed on separate platform scales, with provision for filling from the hydrant. A Blake double-plunger feed-pump, supplied with steam from the boiler on trial, was placed between the tanks, and its suction-pipe was provided with a rubber hose, whereby the pump could be made to take water at will from either tank. This pump was used on all the trials, and whenever it was attached to a new boiler, precaution was taken to see that the feed-pipe was tight, and that all other connections of the boiler to other pumps or injectors were broken off.

After filling a tank with water from the hydrant, its gross weight was noted, and after it had been pumped out almost dry, the suction-hose of the pump was shifted to tank No. 2 (previously filled and weighed), and the gross tare of tank No. 1 was taken; the difference between the gross initial weight and the gross tare being the net weight of water pumped into the boiler. Tank No. 1 was then refilled and its gross weight again noted, when it stood ready to supply the pump as soon as tank No. 2 should be emptied.

The temperature of the feed-water was observed twice in each of the tanks. In the logs will be found the gross weights and gross tares of the tank, together with the times at which hose was shifted, and the heights of water in the boiler at those times, also the temperatures of feed-water. The measurements of the feed-water and the running of the pump were intrusted to one assistant.

Another assistant had charge of the coal accounts, and also took half-hourly observations of the temperatures of the outside air, of the fire-room, steam, pyrometer, water-level, and steam-pressure. This latter observation was taken from the gauge mentioned above, attached just below the stop-valve. A recording gauge was also attached to

RESULTS OF THE

Name of Boiler.	Average steam pressure in boiler, above atmosphere.	Average temperature of steam.	Average temperature of up-take.	Average temperature of feed water.	Average amount of coal consumed per sq. foot of grate per hour.	Number of pounds of water actually evaporated per pound of coal.	Number of pounds of water actually evaporated per pound of combustible.
Wiegand, . . .	70·029	313·17	523·81	70·80	12·32	8·219	9·097
Harrison, . . .	70·03	310·76	517·50	71·16	12·30	8·036	8·785
Firmenich, . .	70·059	356·17	415·50	68·95	11·79	8·927	9·956
Rogers & Black,	70·30	309·76	571·75	67·11	....	7·266	8·059
Andrews, . . .	70·059	328·47	419·60	65·44	8·05	7·985	8·904
Root, ...	69·94	312·50	393·33	64·59	9·09	8·889	9·930
Kelly, ...	69·95	310·00	....	66·95	10 82	7·858	8·636
Exeter, . . .	70·00	308·00	429 94	68·93	9·35	7·276	8·213
Lowe, ...	70·00	309·00	332·29	66·44	6·805	8·758	9·873
Babcock & Wilcox	70·00	389·06	295·82	63·98	9·77	8·812	8·908
Smith,[i] . . .	....	....	....	....	....	....	....
Galloway, . .	70·06	310·06	303·00	55·95	8·87	8·514	9·580
Galloway,[ii] . .	70·12	310·06	324·62	55·12	7·269	9·182	10·069
Anderson, . .	70·00	322·75	417·00	54·00	9·747	7·918	8·727
Pierce, . . .	70·00	312·94	373·82	53·20	7·99	7·419	8·336

[i] No Table of Results of the Smith Boiler was furnished.

[ii] This test was made with Bituminous Coal.

TESTS FOR ECONOMY.

Average actual amount of water evaporated per hour. Pounds.	Number of pounds of water actually evaporated per sq. foot of heating surface, per hour.	Percentage of moisture in steam.	Number of degrees superheated (steam).	Number of lbs. of saturated steam evaporated at 70 lbs. from 212° equivalent to total heat units derived from the fuel.			Rating of boiler on the basis of 12½ sq. feet of heating surface per horse-power.	Rating of boiler on the basis of 30 lbs. of water actually evaporated per horse-power, per hour.
				Per pound of coal.	Per pound of combustible.	Per sq. ft. of heating surface per hr.		
4255·36	3·14	....	13·40	9·463	10·461	3·618	108·40	141·85
2285·73	2·532	1·11	....	9·167	10·022	2·894	72·06	76·19
1654·20	1·533	....	26·70	10·340	11·530	1·775	86·31	55·14
1320·57	3·30	2·68	....	8·397	9·313	3·810	31·98	44·019
1183·74	2·19	....	52·59	9·428	10·513	2·590	43·20	39·46
3393·33	2·217	....	23·16	10·352	11·565	2·485	127·20	113·11
2338·56	3·532	5·97	....	9·189	10·099	4·131	52·96	7·795
2041·70	1·338	4·63	....	8·643	9·756	1·589	122·04	68·06
1341·18	1·731	....	1·05	10·190	11·489	2·014	61·97	44·71
3919·81	2·33	3·24	....	10·211	11·489	2·701	134·40	130·66
....	....	....	....	....	....	....	....	....
2945·71	3·026	0·22	....	9·942	11·187	3·533	77·88	98·19
2603·02	2·673	0·57	....	10·689	11·720	3·113	77·88	86·77
2778·81	2·448	....	14·88	9·305	10·255	2·877	90·08	92·63
1484·61	7·406	5·53	....	8·738	9·818	8·714	16·03	39·48

the boiler, and served to detect any negligence on the part of the man stationed on top of the boiler to regulate pressure. The barometric pressures given in the logs were not observed in the fire-room. Necessary data were kindly furnished by the Signal Station, U. S. A., and proper corrections were made for level and temperature.

The records of the temperature of steam, as shown in the logs and given by a mercury thermometer, are undoubtedly too low. I found that in certain cases, when a draft would blow over the boiler, the simple fact of covering the stem of the thermometer would cause the mercury to rise 10 or 15 degrees. However, it may be seen that, although the temperatures shown by thermometer fall short of the temperatures indicated by calorimeter, the variations in both sets of records correspond.

COAL AND FIRING.

The coal used in all the trials was anthracite coal from the Lea Colliery, Wilkesbarre, Pennsylvania, and was the same as was supplied regularly to the Bureau of Machinery; it was nearly all uniform in size; in quality it varied somewhat, as shown in the following table:

Percentage of Refuse from Coal.

	Capacity Test.	Economy Test.		Capacity Test.	Economy Test.
Wiegand,	8·487	9·537	Exeter,	9·265	11·405
Harrison,	8·369	8·526	Lowe,	10·640	11·286
Firmenich,	8·625	10·338	Babcock & Wilcox,	7·845	10·237
Rogers & Black,	8·373	9·835	Galloway,	11·055	11·128
Andrews,	9·428	10·319	Anderson,	8·684	9·261
Root,	9·67	10·48	Pierce,	8·401	11·600
Kelly,	8·67	9·01			

The coal for the trials was by no means selected or picked, but taken as it came, the prevailing object throughout the test being to get at average working conditions.

The two regular trials for economy and capacity were repeated on the Galloway boiler with bituminous coal, that boiler being proportioned for that kind of fuel. The coal used was George's Creek bituminous coal; it was of very fair quality, but necessitated constant attention to the fires, as it ran and caked very freely on the grates.

The firing was left entirely to the judgment of the exhibitors and their men.

CALORIMETRIC OBSERVATIONS.

Of the several methods for ascertaining the amount of water carried over with steam from a boiler, the calorimetric investigation of the quality of steam, first applied in 1859 by Prof. G. A. Hirn, is the most simple, the most direct, and the most accurate. At the same time it is so practical that it should certainly come into general use. The principle of this method is to condense a certain weight of steam in a given weight of water contained in a vessel, the temperature of which is thereby increased; the number of heat units imparted to the water (its weight multiplied by the increase in temperature) represents the amount of heat liberated by the steam in condensing, and then cooling down to the temperature at which both the water originally in the tank and that formed by the condensed steam stand at the end of the operation.

In these tests the calorimeter consisted of a plain wooden barrel, provided with a suitable stirring apparatus, and placed on a platform scale; a drain-pipe was attached to the bottom of the barrel, and provision was made for filling the barrel with water from the hydrant. Into a vertical portion of the steam-pipe of the boiler, and close to and below the stop-valve, was screwed a short horizontal piece of $\frac{3}{4}$-inch pipe, which was screwed in until it touched the opposite side of the steam-pipe. A row of small holes was drilled on one side of the $\frac{3}{4}$-inch nipple, and in attaching it care was taken that the holes should be turned downward, the object of this contrivance being to catch steam from all the portions of the ascending stream in the steam-pipe. To the $\frac{3}{4}$-inch nipple was attached a $\frac{3}{4}$-inch pipe, felted throughout its length, and running to within a couple of feet of the calorimeter barrel. At the end of this pipe was attached a $\frac{1}{2}$-inch globe valve, and beyond that was fastened a 1-inch hose about five feet long. The observations were taken every twenty minutes in the following manner: The barrel was filled with water from the hydrant, and the gross weight and the temperature were noted. The globe valve on the $\frac{3}{4}$-inch steam-pipe was opened just enough to puff out all water which might have collected in the pipe; then the end of the hose was dipped in the water in the barrel, and the globe valve opened wide. At the same time a signal was given with a gong for the man on top of the boiler to note the steam-pressure. The water was agitated in the calorimeter barrel so as to insure a thorough distribution of the heat throughout the mass of water. When the

temperature in the barrel had been raised sufficiently, the globe valve was closed; the signal was repeated for the man on top of the boiler to note the steam-pressure again, and the temperature of the water in the barrel was carefully observed; then, after taking the hose out of the water, and letting drip from it into the barrel all water which might have been lifted with it, the final gross weight was taken, the increase in weight representing the steam (with water primed, if any) brought into the barrel.

During the progress of a calorimetric observation the man on the top of the boiler was not allowed to touch the stop-valve, in order to prevent changing the conditions of steam.

The duration of the calorimetric experiments varied somewhat. It was attempted as a rule to reach a final temperature in the barrel as many degrees above the temperature of the surrounding atmosphere as the initial temperature was below, the object being to compensate for loss and absorption of heat through the surface.

All things being equal, the duration of the experiment was governed by the quality of steam, as the hotter the steam the less time it would take to heat the contents of the barrel. This may seem useless to mention, still, it showed the sensitiveness of the apparatus.

The calorimeter data are given in the logs. The weight of the barrel is also given; it is the mean of two weighings at the beginning and the end of the trial. An allowance has been made, in computing the results, for the iron stirring apparatus in the barrel, which has to be heated every time, with the water. The weight of the stirrer, multiplied by the specific heat of iron, has been added in all cases to the net amount of water heated.

A New Washing Fluid.—Beat 1 kilogramme of soap, with a little water, into a paste, warm it moderately, and incorporate it, by thorough stirring, into 45 litres of water at a temperature of about 30° C. (86° F.), to which 1 tablespoonful of oil of turpentine and 2 tablespoonfuls of ammonia have been added. The articles to be washed are to be soaked in this mixture for two hours, and then washed as usual. The fluid can be rewarmed and used a second time, by adding more turpentine and ammonia. The process is said to be time, labor and money-saving, much less soap and rubbing being needed, and the wear of the clothes is greatly diminished.—*Neueste Erfind. u. Erfahr.; Pap. Zeit.*, May 3. C.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. civ, page 48.]

P. W. Hofmann[ii] communicated to the German Chemical Society, that if sulphurous acid is conducted into sulphuric acid, saturated with nitric acid, and of the sp. gr. 1·7, the nitric acid is reduced to compounds which combine with the concentrated sulphuric acid present to form the so-called chamber crystals, without the production of appreciable quantities of nitrous oxide. A different behavior was observed if the acid saturated with nitric acid has, *e. g.*, the sp. gr. 1·5, instead of 1·7. In this case the sulphurous acid attacks the nitric acid more profoundly, and there is formed a not unimportant quantity of nitrogen, or—which for the sulphuric acid maker is practically the same thing—of nitrous oxide. The explanation must doubtless be sought in the fact that in the latter case no concentrated sulphuric acid is present with which the higher oxides of nitrogen might unite to form chamber crystals. These facts having been established he sought to turn them to account in the manufacture of sulphuric acid as follows:

In the first chamber he diminished the jet of steam in such a manner that only acid of sp. gr. 1·7 was produced, and he found the laboratory experiments confirmed in such a manner that a much smaller quantity of nitric acid was needful for an equal amount of sulphuric acid. If the precaution is observed that whenever the sp. gr. of the chamber acid incidentally falls, it is raised again to 1·7 by the addition of monohydrated acid, a reduction of the consumption of nitric acid is effected to the extent of 1 kilo. per 100 kilos. sulphur.

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[i] "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

[ii] P. W. Hofmann, *Ber. Chem. Gesell.*, 1870, 5.

In the *Chemical News*[i] the proposal of P. W. Hofmann, to which reference has been made, has been discussed at length by Gibbons, Peter Spence, and others, and the process has been already experimentally introduced into certain German establishments. In 1867 Winckler[ii] published some interesting investigations on the chemical processes which take place in the Gay-Lussac condensing towers. The following conclusions may be drawn from his experiments:

a. Nitric oxide is not absorbed by hydrated sulphuric acid.

b. Hydrated sulphuric acid combines with nitrous acid energetically and with the evolution of heat. The compound is intimate and truly chemical; it is not decomposed by a considerable elevation of temperature, but is immediately broken up on the addition of water. In the manufacture of sulphuric acid this compound is formed in a solid state in the so-called chamber crystals, whilst it is met with dissolved in a liquid state in the sulphuric acid flowing out of the coke towers of Gay-Lussac's apparatus. Nitric oxide and oxygen do not, in presence of hydrated sulphuric acid, combine as usual to form hyponitric acid, but form nitrous acid, even when the oxygen is in excess.

c. Hyponitric acid, both in the liquid and the gaseous condition, is capable of combining with the hydrated sulphuric acid. The compound, however, if truly chemical is very unstable. On the application of heat it is completely decomposed, and the hyponitric acid either escapes unchanged or is resolved into nitrous acid, which enters into chemical combination with the sulphuric acid, and into oxygen which is set free. The mode of decomposition depends on the degree of concentration of the sulphuric acid.

d. Sulphuric acid and nitric acid appear to form mere mechanical mixtures, which, when heated, are resolved into escaping nitric acid, oxygen gas, and nitrous sulphuric acid.

e. Nitrous sulphuric acid, in presence of moisture, forms, on contact, hydrated sulphuric acid, while nitric oxide gas is evolved.

f. Hyponitric acid, in contact with moist sulphurous acid, forms nitrous sulphuric acid in a solid crystalline state.

Ten years ago most sulphuric acid works were unprovided with the Gay-Lussac tower for absorbing the nitrous acid which escapes at the

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i *Chemical News*, 1870, pp. 106, 132, 141, 164, 189, 200, 212, 224.

ii Winckler, in the work cited.

end of the lead chambers. In many cases such a tower had been erected, but was not in use. Gay-Lussac, along with Lacroix, introduced his process at Chauny, in the department of Aisne, as early as 1842, in order to absorb the nitrogen compounds escaping from the chambers in concentrated sulphuric acid, and thus to make them capable of re-utilization. These experiments were undertaken, therefore, at a time when the acid was prepared almost exclusively from sulphur. In establishments where sulphur is in use, the evolution of the gas is generally regular, and hence at that time the results were satisfactory as regards the consumption of nitre. On the introduction of pyrites, especially when the original and imperfect kilns were employed, the influx of gas became less regular, the process in the chambers becoming thus liable to manifold disturbances. Gay-Lussac's apparatus therefore began to yield bad results. At the present day, since Gerstenhöfer and Schwarzenberg have calculated the composition of the kiln gases theoretically most advantageous, since we have learned to check over the composition of the gases by a simple determination of the sulphurous acid, and since more light has been thrown upon the whole process of the formation of sulphuric acid by the researches of Weber and Winckler, a regular production of gas is obtained from the pyrites kilns. The apparatus of Gay-Lussac was therefore introduced at Freiberg in 1865, and has been so managed that the results surpassed everything previously known as concerns the consumption of sulphuric acid. Gerstenhöfer has the merit of contributing to these successes, and of circulating the experience obtained at Freiberg. At Aussig, Liesing, Hautmont, Berlin, Brussels, Griesheim, Hanover, Stolberg, and elsewhere, Gay-Lussac's towers on the Freiberg pattern have been introduced. Since regular determinations of the sulphurous acid in the kiln gases have been made on Reich's method, and since the tower acid from Gay-Lussac's apparatus has been regularly tested for nitrous acid, as proposed by Winckler, a new era in the manufacture of sulphuric acid has been opened. The details of the apparatus as at first used in Freiberg have been given by Schwarzenberg,[1] who also describes the wheel first employed by Segner at Aussig, for the regular moistening of the coke in the towers.

[1] "Handbuch der Chemischen Technologie," von P. Bolley, 2 Band, 1 Gruppe, von Dr. P. Schwarzenberg.

The decomposition of the nitrous sulphuric acid was formerly effected by steam in a so-called "boiling drum." As this apparatus requires frequent repairs, in some establishments the nitrous sulphuric acid is allowed to flow together with water in cascades of earthen vessels placed within the chamber, when the decomposition takes place. Recently Glover's tower, which will be described in the next section, has been used for this object with the best results. A mixture of chamber acid and nitrous sulphuric acid flows from Gay-Lussac's apparatus down into Glover's tower. The hot kiln gases enter from below and concentrate the sulphuric acid to sp. gr. 1·7. The aqueous vapors thus evolved with the aid of the sulphurous acid decompose the nitrous sulphuric acid so completely that the concentrated acid from Glover's tower is perfectly free from nitrogen compounds, whilst the decomposition in the boiling drum and with the cascade can hardly be so conducted, but that imperfectly decomposed acid now and then escapes.

As regards the construction of the chambers, opinions vary concerning the most advantageous form. A. W. Hofmann,[i] in the Report of the London Exhibition, pronounced the formation of sulphuric acid independent of surface action, a view confirmed by the experience of many old manufacturers. Stass[ii] has also proved by experiments at the chemical works of De Hemptine, at Brussels, that, other conditions being equal, the formation of sulphuric acid is proportional to the volume of the chambers. Smith,[iii] in the pamphlet which we have repeatedly quoted, maintains that the interior of the chambers is a still unexplored land, and as a contribution to its exploration he gives some interesting statements as to the proportion of sulphurous acid, nitric acid, and sulphuric acid present in the chamber gases. Among other points he finds that the formation of acid is greatest in the vicinity of the acid already formed, and considers himself justified in concluding that the best shape for chambers is a height of 3 metres, a width of 9, and a length of 60. The author has not found the views of Smith to hold good. He suspended leaden capsules of equal sizes at different heights in the chambers covered with lids at the height of 30 c.m. from each, and determined the amount of sulphuric acid formed in each in an equal time.

i A. W. Hofmann, "Reports by the Juries," p. 99.

ii A. W. Hofmann, "Reports by the Juries," p. 14.

iii Smith, "Chemistry of Sulphuric Acid Manufacture," p. 22.

Smith has probably drawn gases out of the chamber by aspiration, and determined the sulphuric acid therein. It is plain that even if sulphuric acid is formed equally in all parts, the samples drawn below must contain a larger proportion of acid, since that which is formed in the higher part of the chamber must fall downwards. Smith seems, therefore, in this case not to have drawn the right conclusion from his observations.

From the production of sulphuric acid at different heights in the chamber, which for an equal cubic space was approximately equal, Hasenclever inferred that within certain limits, a chamber was the better the fewer square metres of sheet lead it required for a metre of cubic contents.

The lead chamber which Hasenclever has lately constructed for the Rhenania Chemical Works, near Stolberg, is 10 metres high, 10 broad, and 40 long, and requires, therefore, 0·45 square metre of sheet lead for a cubic metre of volume. In almost all earlier chambers the consumption of lead was greater.[1]

Calculation of the Yield of Acid.—As to the amount of real acid present in the aqueous sulphuric acid, several tables, more or less mutually discordant, are used in chemical works. In the recent manuals of Graham-Otto, Wagner, Bolley (Schwarzenberg), and others, the statements of Bineau have been adopted as the most accurate. But in many manufactories calculations are still based on the earlier statements of Vanquelin, d'Arcet, Dalton, and Ure. In drawing up the latter tables, it is assumed that the sulphuric acid of commerce at 66° B. is not a pure hydrate, but contains, at sp. gr. 1·830, 6 to 7 per cent. of water more than H_2SO_4. Latterly Kolb[ii] has published detailed and accurate investigations on the proportion

[1] In connection with the author's communications on the process in the chambers, we mention the recent proposal of Sprengel (English patent No. 3189, A.D. 1873) to supply the chamber with pulverized water instead of with steam. The water in the interior of the chamber is converted into a mist by forcing air or steam into a stream of water. The apparatus by which this comminution of the water is effected, is founded on the same principle as the "*pulverisateur*" used in medicine, or the "*refraichisseur*" of the perfumers, known in England as the "atomizer." The advantage of the introduction of pulverized water is, chiefly, an economy in fuel. According to reports which have reached the Editor, this water-dust has been already advantageously introduced in several establishments. In works which employ the Glover tower this improvement is of little value.—A. W. H.

[ii] J. Kolb, *Bull. Industr. de Mulhouse*, Feb. 28, 1872.

of monohydrate in acids of different specific gravities, which in a great measure confirm the statements of Bineau. The discrepancy which has hitherto prevailed in this respect, depends not on the unequal proportions shown by different tables, but on the unequal graduation of the Beaumé hydrometers. Gerlach[i] has given an interesting conspectus of the specific gravities answering to the single degrees of the scale hydrometer.

As in sulphuric acid works Beaumé's scale is chiefly employed,[ii] a concordant graduation of this hydrometer is much to be desired. Kolb in his tables has introduced a new graduation, since adopted by many, where 0° B. = the sp. gr. of water at 15° C., and 66° B. = the sp. gr. of monohydrated sulphuric acid at 15° C. (= 1·842). The relation between Beaumé and specific gravity is consequently expressed by the equation

$$d = \frac{144{\cdot}3}{144{\cdot}3 - n},$$

d expressing the sp. gr. and n the degree of Beaumé.[iii]

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[i] Gerlach, *Dingl. Pol. Journ.*, cxcviii, 313.

[ii] This, of course, refers only to the continent.—Ed. *C. N.*

[iii] As Beaumé's hydrometer is still almost exclusively used in chemical manufactures, the above formula, especially for laboratory use, is of considerable interest, and a closer investigation of its origin may not be unremunerative. If a hydrometer sinks in water to 0°, in another liquid D, of the sp. gr. d, only to n°, the two unequal volumes of displaced liquid have each the same weight, *i. e.*, the weight of the hydrometer. If we call the weight of this hydrometer G—the weight of a volume of water corresponding to the volume of a degree of the scale being taken as unity—we have the weight of the volume of water displaced by the hydrometer = G; the weight of an equal volume of the liquid D of sp. gr. d = G d; the weight of the water displaced by n degrees of the scale = n; the weight of an equal volume of D = $n\,d$. This latter weight is the difference between the weights G d and G, and we have therefore

$$G\,d - G = n\,d;\ \text{whence}\ d = \frac{G}{G - n}\ \text{and}\ G = \frac{n\,d}{d - 1}.$$

For the case of monohydrated sulphuric acid of sp. gr. 1·842 in which at 15° C. Beaumé's hydrometer sinks to 66°, we substitute these values in the last formula for d and n, and for G we put the number 144·3, and we have then—

$$d = \frac{144{\cdot}3}{144{\cdot}3 - n}.$$

The number 144·3 represents the weight of the hydrometer if the weight of the volume of water corresponding to the volume of a degree of the scale is taken as unity.—A. W. H.

It would be highly desirable if all manufacturers of sulphuric acid would base their calculations on the same tables, for in statements on the yield of sulphuric acid at 66° B. from pyrites or sulphur, different tables are often used, so that the results of different works are not directly comparable.

The following conspectus of the statements of different tables may be of interest in this respect.[1]

Degree of Beaumé.	Sp.Gr. according to Kolb.	Proportion of Monohydrate according to							
		Vauquelin.	d'Arcet.	Tables of Various Works.				Bineau.	Kolb.
10	1·075	11·73	—	11·5	11·40	—	10·98	11·0	10·8
20	1·162	24·01	—	23·3	23·46	—	21·97	22·4	22·2
30	1·263	36·52	—	36·9	36·60	—	35·93	34·9	34·7
40	1·383	50·41	—	51·6	51·49	—	49·94	48·4	48·3
50	1·530	66·54	66·45	66·9	66·17	63·8	63·92	62·7	62·5
60	1·711	84·22	82·34	83·3	82·80	79·4	79·90	78·0	78·1
66	1·842	100·00	100·00	100·0	100·00	94·0	97·87	100·0	100·0

(To be continued.)

Necessity of Light to Vegetation.—M. Boussingault concludes from his own observations, and from the experiments of MM. Pasteur and Ramlin, that "if the solar radiation ceased, not only the plants which have chlorophyl, but also those which are deprived of it, would disappear from the earth's surface." He relies for his data, especially upon his recent observations of "the growth of maize in an atmosphere devoid of carbonic acid," and upon the following experiment, which he performed in 1856: Two seeds of *Helianthus Argophyllus* were planted in calcined siliceous sand, and moistened with distilled water. Nitrate of potash, basic phosphate of lime, and white siliceous hay-ashes were mixed with the sand. In ninety-two days the stalks, the leaves and the flowers of the two plants acquired the same dimensions as those of a *Helianthus* cultivated in the border of a garden for purposes of comparison. This illustrated what the experimenter and M. Dumas have called the "creative power" of plants; the roots acting in sand which contained, in place of the putrefying organic remains which are found in a fertile soil, only pure mineral salts, acting normally, while the plant assimilates the atmos-

[1] Till very recently the sp. gr. of monohydrated sulphuric acid was given as 1·848. See, *e. g.*, "Handbook of Chemistry," by Leopold Gmelin, vol. ii. p. 184 (Cavendish Society's edition).

pheric carbon and organizes the nitrogenous principles of milk, blood and flesh. "Animals do not create, they only transform the principles which are elaborated by the plants." The investigations of eminent physiologists, Mohl, Nägeli, Hofmeister, Sachs and others, show that leaves which are provided with granules of chlorophyl, when exposed to light in contact with carbonic acid and water, give birth to starch, sugar and other analogous substances, such as mannite and lactine, as well as to an emission of oxygen. The presence or the absence of green protoplasm, establishes two orders of cells—those which introduce materials into the organism, and those which introduce nothing, but in which the principles, formed under the double influence of chlorophyl and light, undergo, like the albuminoids, great modifications, either by oxidation or by the intervention of ferments. Similar changes take place in the epidermic cells and in the fluids of the animal kingdom; hence the liver, the lungs, the blood, the milk, contain fat, sugar, inosite, the glycogen discovered by Claude Bernard, of which the properties and the composition are the same as in starch. There are, undoubtedly, plants of a lower order which have no need of chlorophyl or of solar radiation, to build up the materials which are found in the higher organisms of the vegetable kingdom; but there is no living cell which can form a carbonaceous principle, unless it has the faculty of dissociating carbonic acid gas. Plants without chlorophyl, such as mushrooms and yeast cells, are parasites, owing their existence to foreign organisms which have already done part of their work for them. The higher plants, by the co-operation of chlorophyl and light, take all their elements from the mineral kingdom, carbon from the air, oxygen and hydrogen from water. Parasites, on the contrary, take their carbon from substances which have been formed in chlorophyl plants, under the influence of solar radiation. C.

Identity of Motor and Sensitive Nerves.—If a sensitive nerve is pinched, we know that an excitement is sent to the brain; but it is not easy to learn whether any excitement is sent in the opposite direction. M. P. Bert has repeated an experiment, which he first made in 1863, of skinning the end of a rat's tail and grafting it in its back, so as to make a tail in the form of a handle. After the wound has thoroughly healed, he divides the tail, and finds that each extremity is sensitive.—*C. R.*, Jan. 22. C.

WEIGHTS AND MEASURES, DECIMAL.

By S. F. Gates.

The Journal has been the receptacle, from time to time, of reports and communications concerning the various systems of weights and measures for the United States, and within the year past the French system and the metre have been reported upon. With this, an effort will be made to present the decimal (metric) system, using the English foot as the unit of length, instead of the French metre of 39·37 inches, with the hope and desire that we shall find it of more practical use or advantage, than there is, or has been, claimed for the so-called metric system.

To change the decimal scale to any other that may be considered to be better or more convenient in arithmetic, is not the object, but to harmonize the English units of length, weight and capacity, and present the decimal system in such a way as to make it acceptable to everybody.

During my extensive investigations of the metre, the objections to it as the only system for constant and common use by all trades and callings, became positive. The desire to find an arrangement that would answer the purpose, in a decimal ratio, and be agreeable to the English foot as a substitute for the metre, prompted me to look about and see what could be done, and (after I had in mind the basis or formation of what appeared to be a good arrangement) I found reference made to the way I had in view in the last part of the report of your committee (majority report), dated April 19th, 1876; and since that, in the lecture of Sir John Herschel, on the pendulum, the yard and the metre.

"In this lecture the subject is examined from the standpoint of "exact science, and in this regard it is well worthy of attention."

The lecture of Sir John Herschel antedates any effort I have made in this direction. It is pleasing and helps to come to a conclusion, and, I hope, rid us of the irritating contest into which the

[1] See page 7 of the preface to the Metric System, by Charles Davies, LL. D. Published by A. L. Barnes & Co., New York and Chicago. For the lecture in full, see page 319 of the same book.

advocates of the metre have endeavored to force some of us (mechanics and practical men), without a justifiable reason.

The lecturer says: "30. If we are to legislate at all on the sub-"ject then, the enactment ought to be to increase our present "standard yard (and of course all its multiples and submultiples) "by one precise thousandth part of their present lengths, and we "should then be in possession of a system of linear measure the "purest and most ideally perfect imaginable. The change, so far "as relates to any practical transaction, commercial, engineering "or architectural, would be absolutely unfelt, as there is no con-"tract for work, even on the largest scale, and no question of "ordinary mercantile profit or loss, in which one *per mille* in "measure or in coin would create the smallest difficulty. Neither "could it be doubted that our example would be very speedily fol-"lowed both in America and Russia, so soon as the reason of the "thing and the trifling amount of the change came to be under-"stood."

There are other reasons in favor of the arrangement.

SYSTEM.

The foot to be slightly increased in its length, as proposed or arranged by Sir John Herschel, as the scientific unit of length instead of the yard.

Divide the foot into ten parts or *decimal inches*, as well as into twelve parts or inches. This will give us the advantage of two divisions or scales of the foot; both are of service.

Subdivide the foot into tenths, hundredths or thousandths, or carry the decimal divisions to any extent that is desired for the finest measurements or calculations, as now in use to some extent.

Measure of capacity and solid, unit, the cubic foot.

The smaller unit, the cube of $\frac{1}{10}$ of the lineal foot (cubic decimal inch, $\frac{1}{1000}$ part of the cubic foot), and equivalent to one ounce avoirdupois weight.

Measure of surfaces, unit, the square foot.

LIQUID MEASURE.

This part of the system is where the difference is, or has been, and there is the want of a correct proportion or harmony of weight,

length and capacity, in the modern or extremely scientific way of proportioning the whole system to a certain amount of distilled water, under the present admitted or agreed upon conditions, and in conformity with the French measures or system.

The probability is, at the time the system of weights and measures used by the English was discovered or arranged (many centuries ago), chemistry and the science of distilling water were not known, or carried to that extent that they are at the present time, and a certain kind of spring water or sea water was made use of as a basis.

The variation or increased density of water, can be very easily effected, and the required specific gravity to the cubic foot realized without increasing its capacity, and sustain the value of the avoirdupois ounce. Taking this into consideration, it leaves one to believe that the French system (without the metre), as a system, existed and may yet prove to have been in use before the metre was presented to the National Assembly of France, with so much pomp and ceremony, less than one hundred years since.

The decimal unit of capacity or liquid measure in the English system, is wanting; there may be more than one way of making it, but *the gallon is not the proper unit of liquid measure.*

Sir John Herschel, in his lecture referred to, says: "As regards "our measures of *capacity*, the connection would be equally con- "secutive, as a decimal one, between the cubic foot and the half- "pint, which, for the purpose in view, ought to have a distinct name "(such as a '*tumbler*,' or a '*rummer*,' or a '*beaker*'), and which "would contain exactly $\frac{1}{100}$ part of a cubic foot, with whatever "liquid or solid matter it might be filled."

Sir John Herschel proposes to call the half-pint measure, or unit of capacity (containing $\frac{1}{100}$ part of a cubic foot), the "beaker."

To appearance, the unit of capacity, or liquid measure, should conform to the ounce or $\frac{1}{1000}$ part of the cubic foot.

The "beaker," or cup,[1] of ten ounces avoirdupois, would conform to the unit of length (the foot). Both may be used, but the decimal divisions of the ounce, as a unit for chemists and fine measurements, would be best.

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1 A large size tea-cup, containing nearly ten ounces of pure water.

DRY MEASURE.

The bushel to be made up of a certain number of ounces in capacity or weight.

There appears to be a need of net and gross weights, and to some extent, with the liquid measures, and bear a similar proportion to the wine measure that the gross ton does to the net ton, this to be allowed as a custom to wholesale purchasers—say 10 or 12 per cent., or such a per cent. as the substance may justify, in addition to the net weights or measures for gross, as well as in numbers, or count.

MEASURES OF WEIGHT.

The avoirdupois ounce of 437·5 grains, as the *unit*, instead of the pound.

The ounce to be the unit or basis of every weight—the pound, the net and gross ton, the gallon or the bushel.

FLUID MEASURE.

The liquid avoirdupois ounce decimally divided.

In making up or compounding a prescription or formula, the grain or the ounce, decimally divided, can be used, and conform to the old or proposed system.

The application of the Greek and Latin terms, is in conformity with the French system, and as an illustration, they would naturally be dispensed with in common or everyday use, there is no need of anything more than to enumerate the units of each weight or measure.

Scientific Revision of English Weights and Measures.

Kilo ounces	(1000)	=	1	cubic foot.	
Hecto "	(100)	=	$\frac{1}{10}$	of a cubic foot.	
Deca "	(10)	=	$\frac{1}{100}$	"	"
Ounce	(1)	=	$\frac{1}{1000}$	"	"
Deci "	($\frac{1}{10}$)	=	$\frac{1}{10000}$	"	"
Centi "	($\frac{1}{100}$)	=	$\frac{1}{100000}$	"	"
Milli "	($\frac{1}{1000}$)	=	$\frac{1}{1000000}$	"	"
1 ounce		=	437·5	grains.	
Deci ounce	($\frac{1}{10}$)	=	43·75	"	
Centi "	($\frac{1}{100}$)	=	4·375	"	
Milli "	($\frac{1}{1000}$)	=	0·4375	"	

Graduated test tubes, glasses, or any instrument for solids, liquids, or elastic fluids, are to be made correctly from the above scale.

The cubic foot of atmospheric air. Its assumed gravity of 1, is the unit of elastic fluids (at present enumerated or represented by grains, in weight), to be decimally divided.

On page 4, of the Report of the Secretary of the Treasury, on the Construction and Distribution of Weights and Measures, dated Washington, D. C., December 31st, 1856, is found the following table of the decimal division of the avoirdupois ounce.

"Those states to which the balances have been delivered have also "been furnished at the same time with a set of avoirdupois ounce "weights, in addition to the above, consisting of the following "pieces:

"One 8	oz. avoirdupois.	0·02	avoir. of silver wire.
4	"	0·01	" " "
2	"	0·005	" " "
1	"	0·004	" " "
0·5	"	0·003	" " "
0·4	"	0·002	" " "
0·3	"	0·001	" " "
0·2	"	0·0005	" " "
0·1	"	0·0004	" " "
0·05	avoir. of silver wire.	0·0003	" " "
0·04	" " "	0 0002	" " "
0·03	" " "	0·0001	" " "

The graduated scale beam, or the notches on the edge of the steel-yards, should be divided and made one ounce, or the decimal portion of the ounce, apart. The poise to be the ounce or its equivalent. On one side of the beam, made long divisions of 16 ounces, or pounds; on the other side of the same beam, long marks or divisions of 10 ounces to conform to the decimal divisions.

This conforms to the decimal system of weights and measures, in connection with the foot, and avoirdupois ounce.

To enumerate or arrange the measures of weights, liquid measures, coin, apothecaries' weight, etc., under their various headings, would be to repeat the decimal divisions of the ounce, or the foot, in the form of the French metric tables, by changing the names of the units.

There are, probably, but few people within the United States who are aware that there is in every state of this nation, a decimal

division of weights, or any portion of the decimal system except the French. The English units of weights and measures prove to be equally convenient in use, and should be sustained.

COIN.

Coins, in their weight and diameter, should harmonize with the foregoing weights and measures.

Siemens' Compressed Glass.—In the Siemens' glass-works at Dresden, there is now manufactured a product which has the same properties as La Bastie's tempered glass, the strength being communicated by the pressure of metallic rolls. Plates can be made, by this method, of much larger dimensions than by La Bastie's. They have a beautiful look, and can be ornamented with the most complicated designs, at a less cost than ordinary glass. Siemens claims that glass manufactured by his process has a greater strength than tempered glass, in the ratio of 5 to 3. When broken it shows a fibrous structure, while La Bastie's is crystalline. For equal thickness the resistance of a plate of compressed glass is from seven to ten times as great as that of an ordinary plate. In trial experiments, performed before the Berlin Polytechnic Society, a lead ball weighing 120 grammes was let fall, from different heights, upon plates arranged horizontally and supported only at the four corners. While an ordinary plate was shivered by the weight falling from a height of three decimetres, the plate of compressed glass of like dimensions broke only when the weight was let fall from a height of three metres, and even then only under the influence of many successive blows.—*Deutsche Polyt. Zeit.; Il Politecnico*, April, 1877. C.

Artificial Gold.—Take 100 parts (by weight) of pure copper, 14 parts zinc or tin, 6 parts magnesia, 3·6 parts sal-ammoniac, 1·8 parts quicklime, 9 parts cream of tartar. Melt the copper, and add gradually the magnesia, sal-ammoniac, quicklime and cream of tartar, each by itself, in the form of powder. Stir the whole for half-an-hour, add the zinc or tin in small pieces, and stir again till the whole is melted. Cover the crucible, and keep the mixture in a molten condition for thirty-five minutes. Remove the dross, and pour the metal into moulds. It has a fine grain, is malleable, and does not easily tarnish.—*Phönix; Pap.-Zeitung*, May 24. C.

INFLUENCE OF PRESSURE ON COMBUSTION.

By L. CAILLETET.

[Translated from the *Comptes Rendus* of February 22d, 1875, for the JOURNAL OF THE FRANKLIN INSTITUTE, by Chief Engineer ISHERWOOD, U. S. Navy.]

In a communication made to the Academy in 1868, M. H. Sainte-Claire Deville developed a complete plan of the researches commenced in his laboratory at the Normal School, and based on combustion under pressure.

The experiments forming the subject of this note, were conducted according to the principles laid down by M. Deville, and although they were not executed in a laboratory with iron sides and sufficiently large to hold the experimenter and his instruments, yet they were performed with apparatus, which, if not allowing precise calometric measures, had the advantage of being able to show how the phenomena of combustion are modified under pressures which could be carried to 30 or 35 atmospheres.

In order to study the modifications effected by pressure upon the luminous, calorific, and chemical rays from a body in ignition, its combustion had to be maintained during a considerable time; and, consequently, quantities of compressed air, sometimes amounting to hundreds of quarts, had to be provided.

The apparatus employed consisted of the pumps and reservoirs for the compressed gas; the pumps had movable cylinders and fixed pistons, and their leather packings were covered with a column of water or glycerine, which both cooled the compressed gas and prevented its regurgitation. Some canvas tubes, coated with caoutchouc, enabled the gas to be easily directed into either the apparatus for combustion, or into the cylindrical reservoirs, which were of wrought iron, and had been tested to 60 atmospheres.

The laboratory apparatus was a hollow iron cylinder, banded, and having a strength exceeding 300 atmospheres. Four apertures, at about the middle of its height, were fitted with: 1st, the conducting tube for the gas; 2d, the evacuating cock; 3d, the manometer; and, 4th, a plate of thick glass for observation inside. Within this

cylinder, which had an interior diameter of 4 inches, and a capacity of about one gallon, either lamps or the substance to be burned could easily be placed. It is closed by a gum joint, pressed by a blunt metallic screw, whose manipulation is facilitated by a system of counterweights.

When a wax candle is placed in the apparatus just described, the brightness of its flame increases with increased pressure of the air introduced. The base of the flame, which in the atmosphere is transparent and slightly blue, becomes white and very luminous; but very soon the phenomena change, thick clouds of smoke fill the apparatus, and escape through the evacuating cock.[1]

The flame viewed across that smoke was reddish; and, when the experiment ended, the candle-wick was found highly carbonized. The combustion had become incomplete, for considerable quantities of soot were deposited, due, without doubt, to the dissociation of the carbureted gases by the increased temperature of the flame; but the increase was not sufficient to burn a red-hot iron file.

The brilliancy of the flame of phosphorus did not seem to augment under pressure. Potassium burned with a violet colored and very brilliant flame.

Some lighted wood charcoal in a small furnace, was placed in the laboratory apparatus, and the pressure of the introduced air raised to 25 atmospheres, but the combustion did not seem more vivid than in free air.

An alcohol lamp, whose wick is only a single thread of cotton, giving in free air a scarcely visible flame, increased rapidly in brilliancy as the pressure increased. Under from 18 to 20 atmospheres, it emitted white light as bright and luminous as that of a wax candle; its spectrum was continuous and more expanded than under the ordinary pressure; and the line *D* alone visible, seemed sensibly widened.

The sulphide of carbon gave, also, a more brilliant and luminous flame than in free air; and in burning did not produce sensible quantities of sulphuric acid.

Zinc and hydrochloric acid were placed together in the laboratory apparatus, so as to furnish a jet of hydrogen, but that gas could not be inflamed. An arrangement of the apparatus was tried to prevent

[1] The production of this smoke cannot be attributed to want of oxygen, because the air which escaped by the evacuating cock, normally maintained the combustion of another candle placed under a bell-glass just outside the apparatus.

the hydrogen produced from being driven back into the flask on the admission of the compressed air; but the experiment did not succeed, owing, doubtless, to the slowness with which the acid attacks zinc under pressure.

To sum up: the dissociation of the carbureted gases from the wax candle, and the appearance of the spectrums examined, show the temperature of the combustion to have increased with the pressure, but not in any very great degree.

The brilliancy assumed by the alcohol flame, as well as the coloring of the flames of sulphur and of the sulphide of carbon, show what intensity the luminous rays can acquire by increase of pressure.

That the chemical rays have a greater activity with increased pressure was also established. For that purpose a number of flattened tubes containing phosphorescent substances were joined to the bottom of a blackened box, placed in grooves or guides before the window of the laboratory apparatus. These substances had been selected in such a manner as to give the colors of the spectrum when exposed for a moment to the rays of the sun. It was discovered that several pyrophores, which were not influenced by a given flame, became luminous when the pressure increased; and that those which were influenced by a flame at ordinary pressure, became more splendid when the body producing that flame was burned under higher pressures.

Heat-Ratio.—W. M. Hicks, in an article on "Some effects of dissociation on the physical properties of gases," says: "If, then, the two atoms of a molecule have separated, there seem only two ways of accounting for it. Either their relative motion becomes so large as to overcome the force of attraction. or some external force must act upon them, which can be nothing else than a reaction between them and some other molecules. The latter is the hypothesis I have adopted in the following investigation." Under this hypothesis, by taking the potential energy of combination of a single molecule at its upper limit, he obtains for the theoretical ratio of heat under constant volume to heat under constant pressure, $\frac{c'}{c} = 1{\cdot}423$. This corresponds precisely with the value found by the writer (Proc. Am. Phil. Soc., xiv, 651), $\frac{c'}{c} = 2\,r^2 \div (r^2 + 4) = 1{\cdot}4232$.—*L., E. and D. Phil. Mag.*, June, 1877. C.

FORCE OF FALLING BODIES.

By J. W. Nystrom, C.E.

My attention has been called to an article on "Force of Falling Bodies," written by Charles H. Haswell, C. & M. E., published on p. 9, in the July number of the Journal, which article ought not to pass unnoticed, lest it may mislead some readers who, possibly, are not better versed in mechanics.

Mr. Haswell's formula, $W v\, 4{\cdot}426 = M$, expresses momentum of a moving or falling body, and not force, as he asserts. $W =$ weight in pounds, or force of gravity of the falling mass, which is a simple physical element. $v =$ final velocity in feet per second of the falling mass, which is also a simple physical element. M is intended to represent force of a falling body in pounds, which ought to be denoted by F, because it is customary to denote *mass* by M.

The product of the two elements $W v$, is a *function*, viz., momentum, which can never express the *element* force.

Mr. Haswell quotes a formula of mine, for force of a falling body:

$$\frac{W h}{d} = M, \quad \text{which should be written} \quad F = \frac{W h}{d}.$$

This formula is derived from the physical laws involved and expressed by the analogy $F : W = h : d$, which is perfectly correct, and agrees with the experiments of Mr. Haswell; but, unfortunately, he did not make his observations and calculations right; $h =$ height of fall of the body; $d =$ depth of resistance in stopping the body's fall.

These two dimensions, h and d, must both be expressed with the same unit of measure, as feet or inches; but Mr. Haswell has expressed h in feet, and d in inches, which obviously makes his calculation wrong.

Mr. Haswell's given data, $W = 1$ pound, $h = 12$ inches, and $d = 0{\cdot}5$ of an inch, make the force,

$$F = \frac{W h}{d} = \frac{1 \times 12}{0{\cdot}5} = 24 \text{ pounds, instead of } 2.$$

When $h = 24$ inches, and $d = 0{\cdot}5$ of an inch, the force of the falling body will be,

$$F = \frac{1 \times 24}{0{\cdot}5} = 48 \text{ pounds, instead of } 4.$$

This last calculation agrees nearly with Mr. Haswell's experiment, which gave 50 pounds; but he evidently did not measure correctly the depth d. In the first case we have the depth,

$$d = \frac{Wh}{F} = \frac{12}{35 \cdot 5} = 0 \cdot 338028 \text{ inch, or } 0 \cdot 028169 \text{ foot.}$$ Second,

$$d = \frac{24}{50} = 0 \cdot 48 \text{ inch, or } 0 \cdot 04 \text{ of a foot.}$$

Mr. Haswell says $d = 0 \cdot 5$ in both cases, which is a physical impossibility.

The fallacy of Mr. Haswell's experiments, with their accompanying formula and expressions, is so palpable that no student of mechanics ought to be misled by them, and it is perfectly correct, as stated by Prof. W. H. Pratt, that Mr. E. E. W. has probably been misled by Haswell.

The following table is given by Mr. Haswell as representing different modes of calculating the force of falling bodies:

Weight and Height of Fall.	Formulæ of W. H. P. $W \times h = M$	G. M. T. $W \times v = M$	P. H. Vander Weyde. $W \times v^2 = M.$	J. W. Nystrom. $\frac{W \times h}{d} = M$	Experiment.
	LBS.	LBS.	LBS.	LBS.	LBS.
1 lb. falling 1 ft	1	8·02	64.33	2 *	35·5
1 lb. falling 2 ft.	2	11·34	122·66	4 †	50

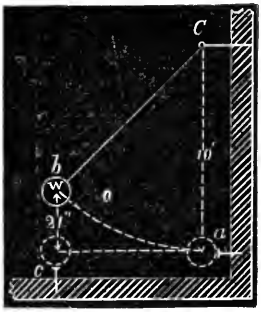
The column headed W. H. P., expresses the function, work in foot-pounds, and *not* the element force in pounds.

The column G. M. T., expresses the function, dynamic momentum, and *not* the element force in pounds.

The column headed P. H. Vander Weyde, has no meaning; but if the formula and numbers be divided by $2g$, the quotients will be work, and *not* pounds.

In a lecture on Technical Mechanics, delivered at the Franklin Institute last winter, I made experiments on finding the force of a

* This should be 24 pounds, and † 48 pounds.



falling body by the aid of a pendulum suspended at c, so as to strike a nail at a. The shaded section represents the wooden wall and floor. The weight $W = 2$ pounds, suspended about 10 feet from c, was drawn to b, at which point it was lifted vertically 21 inches, and left to swing against the nail a, which was thereby driven $\frac{3}{4}$ inch into the wood. The problem was to determine the resistance of the wood to the nail, which was solved as follows:

The work in lifting the weight of 2 pounds a height of 21 inches is 42 inch-pounds.

Calling F the resistance to the nail in the wood, the work of driving the nail was $\frac{3}{4} F$ inch-pounds. Those two works must evidently be alike, or $\frac{3}{4} F = 42$, of which resistance F will be

$$F = \frac{4 \times 42}{3} = 56 \text{ pounds, which is the force of the falling}$$

body.

If the same weight W was dropped vertically from b, a depth of 21 inches on the nail c, it will drive in the nail the same distance, $\frac{3}{4}$ of an inch, provided the resistance in the wood is the same as at a.

When the weight W and striking velocity V in feet per second are known, and d the distance in inches the nail is driven in, the resistance will be

$$F = \frac{3\ W\ V^2}{16\ d}, \quad \text{and} \quad d = \frac{3\ W\ V^2}{16\ F}.$$

Applying this formula to Mr. Haswell's experiment of a weight $W = 1$ pound falling $h = 2$ feet, in which the final velocity became $V = \sqrt{2\ h\ g} = \sqrt{2 \times 2 \times 32{\cdot}13} = 11{\cdot}34$ feet per second, and penetration $d = 0{\cdot}48$ of an inch, the force of the falling body will be

$$F = \frac{3 \times 1 \times 11{\cdot}34^2}{16 \times 0{\cdot}48} = 50{\cdot}221 \text{ pounds.}$$

Mr. Haswell's experiment gave 50 pounds. The number 16 in the denominator should theoretically be 16·085, which would bring the force down to 49·956 pounds, or 0·044 of a pound less than 50.

THE WATER-PRESSURE BLOWING ENGINE.

By Robt. Briggs, C. E.

One of the earliest applications of steam as a motive power was to set a direct acting engine to pumping water to drive the water-wheel of a grist mill, and from the Journal[1] of June it appears that one of the latest ways of utilizing a water-power, is to use it upon a piston, to translate the reciprocating motion obtained in this way to a rotative motion with a fly-wheel, and then return to reciprocation again to operate another piston of an air pump.

This combination appears to the writer so peculiarly undesirable, that he now proposes to call attention to what he thinks to be the mechanical purpose of the fly-wheel as a portion of a motive engine. In such an engine the fly-wheel has its place in transforming a pressure on a piston, with rectilinear movement, to the rotation of a shaft, so as to produce a practically uniform angular motion for the transmission of power. And the fly-wheel becomes available as a reservoir of force to enable the varying power derived from the expansion of steam in a cylinder to overcome the constant resistance of the water column on a pump.

Any mass in motion, is as effective as the mass of a fly-wheel in rotative motion, and in deep mines the use of a heavy weight moving at the low speed of a pump, and coming to rest each stroke, is equally efficient in admitting expansion of steam, with a fly-wheel in constant but varying rotation, where the stroke of the pump is measured by the crank.

There is no mechanical or constructive difficulty whatever in obtaining a direct motion from a water-pressure cylinder to an air cylinder—and it is not by any means a new proposition or accomplishment—but it may be allowed that the plan of interposing a fly-wheel to prevent the easy transmission of uniform piston speed is quite as novel as an example as it is undesirable as a precedent. There is no limit to the sequences of mechanical movements—fly-wheels, cranks, gears, beams, cams, etc., etc., but no power is to be derived from them, and every time one or more are resorted to, fitness and necessity for the purpose in view are what constitute the mechanical merit of the

[1] Vol. ciii, page 398.—Rotative Water-Pressure Engine [Blowing Engine].

selection. In the case of one pump driving another, a simple piston rod is obvious enough, assuredly when it is seen that a perfectly regular water-pressure in a motive cylinder is to impart a perfectly uniform pressure to air in the forcing cylinder. The small irregularity from the compression of air at the beginning of the stroke being productive of too small a loss of efficiency to be worth attempting to gain by a fly-wheel. There is an unlimited choice of ways to effect the motion of the valves and control the length of stroke of such a water-pressure engine—any of the old forms of cataract will do. The Davey movement will control the speed for varying heads of water, or for relief of pressure of the air cylinder. Any form of water-wheel governor can be adopted for a speed regulator. If the engines are coupled (as is shown in the JOURNAL referred to), the Worthington movement of one cylinder operating the valves of the other, and the contrary, is available. If the highest water-power possible were desired, it can be attained by the use of a beam between two cylinders, with an adjustable beam-centre so as to change the stroke of the water cylinder. The good modifications of the water-pressure blowing engine are innumerable; but the particular form which puts in a heavy fly-wheel to disturb the natural regularity of motion, uses air chambers to relieve the artificial disturbances, and, finally, at great cost for original construction, and with large addition to the wearing parts, subjected to inordinate wear, takes the form shown in the JOURNAL, is hardly a good type to copy.

Textile Adulterations.—Thin sections, perpendicular to the axis of the fibres, have furnished M. Vetillart various marks for distinguishing linen from hemp, as well as from jute and other foreign fibres. To those purely microscopic indications he has added others of a chemical nature. A mixture of sulphuric acid and glycerine, acting on fibres which have been previously impregnated with iodine, colors some blue and others yellow, thus establishing two easily distinguishable divisions. A combination of the two methods shows different characteristics in different families, and even gives the means of often distinguishing the different genera of the same family. Thus the anatomical structure of vegetables furnishes data for classification, parallel to those of animal morphology.—*Soc. d'Enc. pour l'Ind. nat.; Les Mondes*, May 24. C.

THE ASHTABULA BRIDGE DISASTER.

An article in the JOURNAL for February, 1877,[1] upon "Governmental Interference for Prevention of Accidents," suggested by the burning of the Brooklyn Theatre and the fall of the Ashtabula Bridge, contains a strong argument in favor of the inspection of railroad bridges by officers to be appointed under an Act of Congress.

The opinions expressed at that time could have no more forcible confirmation than that furnished by the "Report of the joint committee, concerning the Ashtabula Bridge accident, under joint resolution of the General Assembly of Ohio," from which the following extracts are taken.

It will be remembered that this bridge, located near Ashtabula, Ohio, on the line of the Lake Shore Railroad, gave way on the evening of Friday, Dec. 29th, 1876, causing immense loss of life and property. The Ohio Legislature, being then in session, authorized the appointment of a committee to investigate the causes of the accident. On January 16th, the committee was on the spot for the purpose of making personal examinations and taking testimony, and two days later, three engineers, employed to take measurements and make calculations, were also there and at work. The accident was so unusual a one, that it attracted the earnest attention of all the engineers of the country, and several of them visited the wreck and made personal examination without reference to official investigation, and the committee availed themselves of the services of some of them. The witnesses examined included the President of the road, who was also the projector of the bridge, the chief engineer of the road, the master mechanic who constructed, and the carpenter who erected, and the engineer who made the original drawings of the bridge, and a considerable number of experts.

The published report is accompanied by all the testimony and statements made to the committee, by plates showing the general plan and details of the structure, and a draft of a bill to be presented to the Legislature, "to secure greater safety for public travel over bridges," making an 8vo. volume of 158 pages.

"The bridge consisted of two trusses of the Howe-Truss type, executed in iron, and carrying two tracks on the upper chords or deck, and was of the following general dimensions:

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[1] Vol. ciii, p. 75.

"Length of span between abutments,	150 feet.		
" " " centres of half blocks,	154	"	
" of each panel,	11	"	
No. of panels,	14		
Height from centre to centre of chords,	19	"	8 in.
" " out to out,	20	"	$0\frac{3}{8}$ "
Width in clear between trusses,	14	"	0 "
" from out to out of trusses,	19	"	6 "

"The floor-beams were spaced 3 feet 8 inches, centre to centre, and consisted of rolled iron I beams, 4 inches by 6 inches, and were 25 feet 3 inches long, projecting 2 feet $10\frac{1}{2}$ inches over each truss.

"The bridge carried two tracks, 4 feet $8\frac{1}{2}$ inch gauge, the outer rails of which were directly over the centre of each truss.

"The track stringers under the outer rails, consisted of two pieces, 6 inches by 14 inches, and, under the inner rails, three pieces, 6 inches by 14 inches, besides which there were bearing stringers on the outer ends of the floor-beams, each one piece 6 inches by 14 inches, all of white pine.

"The deck was 3 inches thick and 26 feet wide, and was laid *close*, covering the entire surface.

"Along each side of the floor, was a pine-guard rail, 10 inches by 10 inches, bolted through the deck and bearing-girder to the floor-beams.

"Each truss rested on expansion-rollers at the east end."

Of all the information as to the causes of the disaster, that of the three engineers employed is as likely to be based on disinterested engineering skill as any, and, as it agrees in the main points with all the other experts' testimony, is entitled to great weight. They give the following as the result of their examinations and calculations:

"First. That the factors of safety are extremely irregular, and vary through a wide range.

"Second. That all the tension members have very large factors of safety, and were abundantly able to sustain all the strains that could possibly come upon them in this bridge.

"Third. That all compression members, except the counter braces, are deficient in capacity, having very small factors of safety.

"Fourth, shows the factors of safety based on the ultimate *crushing* strength of the metal, without taking into account the tendency to flexure in a long column. Upon this hypothesis the factors of safety are shown to be reasonably large, and correspond more nearly with the factors for the tension members; and it may be that the original calculations were made on this fallacious assumption.

"Fifth. Considered with reference to the location of the break, it appears that the weakest point, as to the braces, was in the third

panel, and that the weakest point in the top chord was at the centre, though the top chord, at the point of failure, does not show a state of security much greater than that of the braces.

"The probability is that the braces failed first, and thereby involved the failure of the top chord also. But inasmuch as both members were weak, and both were involved in the break, it is of little importance which member took precedence in the failure. The factors of safety throughout the compression members were so low that failure must have followed sooner or later.

"If the several groups of beams composing the braces and top chord had each been combined into a single member, by riveting on to their flanges a system of diagonal plates—say three and a half by half inch—running alternately from right to left and from left to right across the entire group, the bridge would have been abundantly safe. This arrangement would have made each group strongest in the lateral direction and weakest in the direction of the webs of the beams; but in this direction the beams offer about five times the resistance that they do laterally. The top chord members could then only deflect in single panel lengths, and on that account their strength would have been still further increased—twofold. The result would have been that the factors of safety given in the tables would have been increased *five times* for the braces and *ten times* for the chord. They would have been so excessively strong that much of the material might have been omitted.

"There were several other defects in this bridge, some of which have been already incidentally alluded to, but which we do not regard as causes of this disaster.

"As to the adaptability of the Howe truss type of bridge for execution in iron, we would say, speaking generally, that any ordinary type of bridge *can* be made abundantly secure, in either iron or wood, if the resisting material is properly proportioned to meet the several strains, and the workmanship is properly executed; and that a failure to provide sufficient materials in any one or more members would be equally fatal in any case. The relative merits of the several types of trusses depend chiefly on questions of economy of construction. The Howe truss type would not be as economical in iron as some others; but if built of proper strength in all its members, would be a good and serviceable bridge.

"In conclusion, we would say that we find nothing in this case to justify the popular apprehension that there may be some inherent defect in iron as a material for bridges. The failure was not due to any defective quality in the iron. It was not owing to the sudden effect of intense cold, for failure occurred by bending, and not by breaking. It was not the result of a weakness gradually developed after the erection of the bridge. It was due simply to the fact that it was not constructed in accordance with certain well-established

engineering principles. We find no evidence of any weakness which could not have been discovered in the plan and avoided in the construction."

As a summary of the whole investigation, the committee, from personal observations and calculations, and a patient and careful consideration of all the evidence within reach, arrive at and report the following conclusions:

"1. There were from eighty to one hundred lives lost by the failure of the bridge.

"2. The bridge went down under an ordinary load by reason of defects in its original construction.

"3. *The defects in the original construction of the bridge could have been discovered at any time after its erection by careful and analytical inspection, such as the importance of the structure demanded, and thus the sacrifice of life and property prevented.*" K.

ON THE MANUFACTURE AND USE OF TERRA-COTTA DRAIN AND SEWER PIPES.

By Prof. L. M. Haupt.

[Contribution from the Department of Civil Engineering, Towne Scientific School, University of Pennsylvania.]

Terra-Cotta is a variety of earthenware, and for pipes in this locality, it is composed of a stiff clay from Woodbridge, N. J., mixed with a substance called "chamotte," which is made of ground up fragments of firebrick and broken pipes which have been burnt. It is prepared in three sizes, known as Nos. 1, 2 and 3, and is used to prevent the pipes from warping or cracking in drying and burning.

The clay is first placed in sheds where it is allowed to season. It is then worked over at least twice in a pug mill, from which, as it issues, it is conveyed by means of buckets on an endless band to the top of a vertical hydraulic press, capable of containing a charge of ten tons (or less). A conical head having an annular aperture equal to the exterior diameter of the pipe to be made, is attached to the bottom of the press, which is elevated on columns; and to prevent the clay from being forced out in a solid mass, a conical plunger is suspended within and just over the aperture, leaving a space equal to

the thickness of the pipe to be formed. The clay is forced out in a continuous vertical stream, and received upon a skip or small platform, placed upon the head of a piston, which descends with an equal velocity. Each length of pipe is cut off by drawing a brass wire across the mouth of the press, and then carried on a low truck to the moulding room.

If bell pipe is to be made, the moulder, whose hands are protected by leather or horn shields, moistens the rim of the clay cylinder, which has been placed on the potter's wheel, turns it out and down, and by gentle pressure, whilst revolving rapidly, forms the desired recess. It is then conveyed to the drying room over the kilns, where it remains until quite hard.

The next operation is that of applying the glaze, which may be done either in the kiln, by sprinkling salt into it when at a white heat, or by dipping each pipe into a solution of Albany earth, a clay possessing the peculiar property of fusing when heated. The first is known as the "salt," the second as the "slip" glaze, and an animated controversy has arisen in regard to the relative merits of the two glazes.

The first is evidently much cheaper, as it is only necessary to sprinkle a bushel or more of salt into the mouth of the kiln, and the operation is complete; but not so the glazing, for the pipes are placed in "nests," that is the smaller ones are inserted in those of larger bore, and supported by the bell at the top, like a telescope, completely closing the interior surfaces of all the pipes except the smallest one, and thus preventing the vapors from reaching them. Even should the glaze cover every portion of the surface, it is not permanent, for from the nature of the ingredients it will contain silicate of soda (Na_2SiO_3), which is "*soluble glass.*" In fact, several specimens of salt glaze have been tested by placing them in an acid solution, which dissolved every particle of the glaze; while the slip glaze, subjected to precisely the same tests, remained untouched.

Slip glazing is performed by placing the pipes upon a grating, which is lowered into a tank containing the Albany earth in solution. In this way, every particle of the pipe, inside and out, is covered, and considerable "slip" is absorbed by the pores of the dry clay, forming not merely an adherent scale, but a homogeneous mass, which is burnt in and vitrifies at the burning of the pipe.

Pieces of slip-glazed pipes, exhumed after many years of use in drains, are found to be unaffected by the sewer gases and in as good condition as when first laid.

The question of terra-cotta *versus* brick for sewer material, is one in which every member of the community is, whether knowingly or not, directly interested. The advantages of the former substance are so self-evident as scarcely to need mentioning; yet, so difficult is it to remove a prejudice or overcome a conservatism rooted in custom, that a series of practical experiments were recently arranged, and a large committee of our City Fathers invited to be present, that they might decide the question of the relative advantages of the two materials.

Two parallel sewers were built, of equal dimensions of aperture and length, on the same grade—one of brick, the other of terra-cotta; and to demonstrate the facility with which solids would pass through, a marble was laid at the upper end of each. It immediately rolled through the terra-cotta pipe, but lodged in the brick sewer at 9″ from the starting point. Buckets of water filled with chips were then thrown in, with a similar result; all the water and chips being carried through the terra-cotta sewer, whilst none of the water nor chips came out from the end of the brick one. To show how freely the noxious gases escaped from our ordinary sewers, some oil waste was ignited and thrown into each, and the ends closed. The result was astonishing, for from every pore of the bricks dense black smoke issued in volumes, whilst hardly the slightest trace was discernible in the other case.

To present a perfectly fair and just comparison, the brick sewer was supported in a trough filled with sand, to sustain the lower segment which is usually laid *dry* upon a cylindrical bed. The upper segment contains some mortar, the whole being held together by the pressure of the surrounding earth. Now, if from any cause the earth be removed from the exterior, the bricks fall and the passage is barricaded. To show the weakness of such construction, the outer plank, forming the trough supporting the brick sewer, was knocked away, when the whole structure suddenly collapsed.

Such accidents frequently happen from leaks, and the myriads of rats that infest these underground passages, undermining the bed of the work.

Another consideration, in favor of terra-cotta, is that of the closeness and neatness of the joints and intersections with other sewers

and drains, and the ease with which they may be given the proper curves, so as not to interrupt the flow of sewage in the main channel, and thus cause deposits.

So *fragrant* are the evils of the brick sewer system, with its open inlets and silt basins where fœcal matter is allowed to putrefy during the summer months, that it is only necessary to pass near one and let it speak for itself. Yet the most subtle and poisonous gases are not those which emit a sensible vapor, but are unperceived until, like the disaster at Wheatland, it is too late. Every day we unconsciously inhale more or less of these deadly vapors unnecessarily, through defective sanitary measures, and from motives of economy, dearly bought. The sewage permeates the bricks and crevices, and saturates the soil, whilst any increase of pressure in the gases of the sewers forces them back through the traps, if there happen to be any, into the streets, unfiltered and foul. This fact is verified by carefully collected statistics, showing in England a reduction in the death rate in every case where effective sanitary works were resorted to. Mr. B. Latham cites twelve cases of cities and towns, with populations ranging from 7818 to 68,056, and death rates varying from $19\frac{1}{10}$ to $33\frac{2}{10}$ per 1000, in which, after the completion of the sanitary works, the rate was reduced to from $18\frac{6}{10}$ to $26\frac{2}{10}$ per thousand, with a diminution in some of typhoid fever cases from 10 to 75 per cent., and from 11 to 49 per cent. in cases of phthisis.

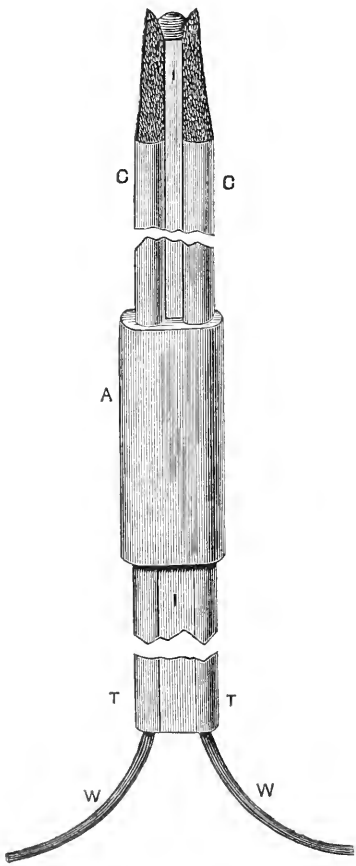
It is estimated that "there are 28 cases of sickness for every unnecessary death" from these causes. As it seldom happens that a sick man is a benefit to, but rather a burden upon, the community, it is of some pecuniary value to increase the health of a locality by all reasonable means. There are many other important considerations bearing directly upon this subject, but they are beyond the scope of this communication. Its aims will have been reached if it excites a more general interest in the matter of improving the health of cities by introducing a more efficient system of sewerage.

Siberian Mammoth.—The recently discovered carcass was in the gold-bearing sands of the river Kundola, at a depth of five metres. The flesh was very soft and of a light red color, when first dug out, but it soon hardened, becoming like a white clay. It seems to be much impregnated with lime.—*Nature.* C.

THE JABLOCHKOFF ELECTRIC CANDLE.

DESCRIPTION.[1]

In the accompanying figure we illustrate the electric candle as used by M. Jablochkoff for his experiments in Paris. The illustration is full size, but reduced in length by breaking, and is reproduced from the French journal, *La Nature*, with a slight alteration of the lettering only. The "candle," as we explained in our issue for May 18th, is



now employed only in cases where a powerful light is required, the simpler porcelain burners being used for lighting purposes where a number of burners of medium intensity are necessary. The "candle" shown is, we believe, not the latest of M. Jablochkoff's designs, but it illustrates definitely the principle upon which his improvements in the electric light are based. *A* is a holder of asbestos, supporting the two carbon rods, *C*, turned to a cylindrical shape, as shown, out of gas retort scale. These rods are held in tubes *T*, of brass, or copper, preferably the latter, and are separated by the insulating material, *I*, consisting of a compound which has received the name of kaolin. When the current passes, being brought to the candle by the wires *W*, the electric arc is produced, and the heat vaporizing the insulating material as the carbons are consumed, the relative distances are always preserved. If a continuous current is used, the double consumption of the positive rod is provided for by making it double

[1] *English Mechanic and World of Science*, June 15th, 1877.

the sectional area of the negative, but the candle works better with alternating currents, in which case the carbons are of the same size. It is easy to reverse the apparatus so that the arc is produced at the lower ends of the rods. The candle may then be employed for an overhead light. One of the principal advantages of this lamp is, that it may be set in operation at a distance. M. Jablochkoff accomplishes this by placing a piece of carbon between the points. When the current passes, this becomes hot, reddens, and finally consumes. Continuity is then broken, and the arc appears. A bit of lead or of fine metallic wire, which melts easily, answers the same purpose. The gradual fusion of the insulating material presents another advantage—namely, that it becomes conductive on attaining the liquid state, and admits of an elongation of the arc, which increases the light. This conductibility, moreover, admits of the re-ignition of the candle after it has been extinguished by the breaking of the circuit, provided the interval is not longer than a couple of seconds. By this means, it has been suggested, the candle might be employed for transmitting signals by flashes, using the Morse telegraphic alphabet and the Mance heliograph.

TRIAL IN LONDON.[1]

On Friday, the 15th inst., a trial was made of the electric lighting apparatus invented by M. Jablochkoff, and known as the "electric candle," at the West India Docks.

"The proceedings commenced soon after 9 P.M., with the lighting of four electric lamps in the court-yard at the entrance of the docks. The lamps were arranged at distances 45 ft. from each other in one direction, and 20 ft. in the other. The light of the electric candle in each lamp was subdued by being transmitted through ground glass globes. The light was steady after the first few minutes, and that of one lamp was sufficient to enable small print to be easily read 20 yards away. The light was produced from one of the Alliance Company's (Paris) electro-magnetic machines, having 32 magnets of six plates each, and being driven by a small portable steam-engine. After burning for a quarter of an hour, the electric lights were extinguished, and four gas-lamps, each having four of Bray's No. 6 burners and four powerful reflectors, were lighted. The con-

[1] *Journal of the Society of Arts*, June 29th, 1877.

trast was very marked, the gas burning with a dull yellow light which barely lighted the surrounding space. The visitors then proceeded to the top story of one of the larger warehouses, which was lighted with three of the electric candles, placed at considerable distances apart, and in the windows of the building. The floor was about 120 ft. long by 65 ft. wide, and the light was most efficient when not obstructed by the shadows of the visitors moving about. A portable electric light was next carried down into the hold of a large vessel, and its efficiency in that respect was fully demonstrated, as it was also by an electric light on the quay. By the aid of these lights, properly arranged, the loading and unloading of ships could be carried on at night. The carbon points, on candles, will only burn for about an hour, but M. Jablochkoff arranges four of these candles on each lamp, and as one is consumed another is ignited by a simple switch arrangement, so that the continuity of the light is hardly broken. The whole of the experiments were highly satisfactory, and indicate an important advance in the utilization of electric light,—firstly, as regards the supersession of clock-work; and secondly, with respect to the divisibility of the stream of electricity, which renders it possible to burn several lights with a single current."

COST.[1]

The experiments, or rather demonstrations to which we have referred, took place at the West India Docks, on Friday evening, June 15th. * * * This notice would not be complete without some data as to the cost of this form of electric light which will be convenient to compare with that of gas.

The four electric candles in the court-yard require two horse power, which costs in London about four pence per hour. In addition, the four lights together consume about half a yard of candle per hour, which may be put at one shilling. The whole expense is therefore, one shilling and four pence per hour for the four electric lights, equaling 400 gas jets, which would cost in London about five shillings. This comparison is as favorable as the demonstration was successful, and we now look forward more confidently than ever to the extended application of this illuminating agent.

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[1] *Iron*, June 30th, 1877.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CIV. SEPTEMBER, 1877. No. 3.

Franklin Institute.

The Institute has decided to purchase, for experimental purposes, a Dynamo-Electric Machine, capable of producing not less than 1200 candles' light. In order to decide what kind of machine to select, it has been determined to invite all builders of such machines to send one of their make to be submitted to a comparative trial.

The trial will be conducted by a committee of scientific men, well qualified to judge of such apparatus. It is expected that their report will embody a description of each machine, a statement of its performance, including the amount of light produced, power required to drive it, and its capability of long continued work without undue heating or derangement.

It is proposed to make these tests early in October, but it is desirable to know at as early a day as possible, what machines will compete. Those entering their machines for this test, will be expected to send them at their own risk and cost, but no expense will accrue in making the tests. It is believed that such a comparative test as is proposed, and the report thereon, will be of great benefit

by increasing the already great interest felt in this country in the introduction of such machines for producing light, and for other industrial purposes.

Communications on this subject should be addressed to the Secretary.

The following donations to the library were reported at the meeting of the Board of Managers, held August 1st, 1877:

Historical Sketch of Schools in Paterson, N. J. By Wm. Nelson. Paterson, 1877. From the Author.

Royal Geographical Society African Exploration Fund. From the Royal Geographical Society.

Almanac Nautico para 1878 media 1877.

Three Photographs of the Arctic Exhibits made by the U. S. Gov't at the International Exhibition, Philadelphia, 1876.

From the U. S. Naval Observatory.

British Patent-Office Publications, as follows:

Specifications from 1001 to 3200. 1876.

Alphabetical Index of Patentees, etc., for 1874–5. 2 vols.

Abridgments of specifications relating to Bleaching, Dyeing, etc. Part 2, 1858–1866, 2d Ed. 1 vol.

Ice-Making Machines, Ice Safes, etc., 1819–1866. 2 vols.

Manure, Part 2, 1856–1866. 1 vol.

Paper, Pasteboard, etc., Part 2. 1 vol.

Printing, 1617–1857. 1 vol.

Roads and Ways, 1619–1866. 1 vol.

Unfermented Beverages, etc., 1774–1866. 2 vols.

Thirteen Patent Specifications, of odd numbers, to fill deficiencies.

Four numbers Commissioner of Patent's Journal, to fill deficiencies.

Nine Disclaimers. From the Commissioner of Patents.

The Employment of Mechanical Motors on Tramways. By W. R. Rowan. London, 1877.

Tramways. Parliamentary Report. 1877.

From Frederick Ransom.

Geological survey of the oil lands of Japan. Report of progress for the first year. By B. S. Lyman. Tokei, 1877. From K. S. Otori.

Thirty-fourth annual report of the Managers of State Lunatic Asylum, Utica, N. Y., for 1876. From the Managers.

Second report from the Committee on Sewage of Towns. London, 1862.

Transactions of the Society of Engineers, for 1876. Edited by P. F. Murray. London, 1877. From the Society.

Quarterly weather report of the Meteorological Office, Part 4, Oct. to Dec., 1876. London, 1877. From the Committee.

Notice necrologique sur Emile Vandrey par MM. H. Rousselle et J. Darcel. From the publisher of Annales des Ponts et Chaussées.

Les Marques de Fabrique Françaises. Paris, 1877. From G. Morgan Eldridge.

Annales des Ponts et Chaussées. Table generales, 5me ser., 1871–1875. Paris, 1876. From M. Dunod, Paris.

J. B. KNIGHT, *Secretary.*

WATER PRESSURE BLOWING ENGINE.

Editors Journal of the Franklin Institute:

We feel compelled to correct the criticisms of Mr. Briggs, on the Longdale Water Blowing Engine, built by the I. P. Morris Co.

First, The water piston and blowing piston are attached to the same rod. The power is transmitted direct from the one piston to the other, except the small excess at the beginning of the stroke, which is transmitted to the opposite engine and utilized.

Second, The power being transmitted direct, there is but little wear on the journals.

Third, The fly-wheels are mere skeletons, light, and counterbalanced to perform their proper work.

Fourth, The cranks determine the stroke exactly, giving a minimum of clearance in the blowing cylinder, and are always to be relied on.

The Worthington duplex-valve movement has been tried, and does not give a uniform stroke. It is liable to stoppages, which prove fatal to parts of the furnace. Flowing water cannot be suddenly stopped without recoil and straining of the containing parts, hence the use of air chambers.

The *When* is given correctly by Mr. Briggs.

The *How* is in error.

The *Why* he has not examined.

The Longdale engines are working economically and satisfactorily, without Davey regulators or governors.

TAWS AND HARTMAN.

"THE GAMUT OF LIGHT."

By Pliny Earle Chase.

In accordance with a suggestion of Dr. Henry Draper, that I should test some of my views by applying them to the spectral lines, I have undertaken a preliminary investigation, with the following result:

In the harmonic progression, $\frac{c}{n}, \frac{c}{n+a}, \frac{c}{n+2a}$, etc., let c = wave-length of Fraunhofer line $A = 761{\cdot}20$ millionths of a millimetre; $n = 1{\cdot}0150$; $a = {\cdot}0918$; and we find the following accordances:

Numerator.	Divisors.	Quotients.	Observed.	Kirchhoff Lines.
761·20	n	749·95	?	?
	$n + a$	687·75	687·49 B	592·7
	$n + 2a$	635·07	634·05	783·8
	$n + 3a$	589·89	589·74 $D\gamma$	1005·8
	$n + 4a$	550·72	550·70	1306·7
	$n + 5a$	516·42	517·15	1655·6
	$n + 6a$	486·14	486·52 F	2080·0
	$n + 7a$	459·22	458·66	2436·5
	$n + 8a$	435·12	435·67	2775·7
	$n + 9a$	413·43	?	?
	$n + 10a$	393·79	393·59 H'	H'

The "observed" values are the wave-lengths, as determined by Dr. Wolcott Gibbs (*Amer. Jour. Sci.* [2], xliii, 4), of the corresponding lines on Kirchhoff's scale. The lines between A and B have not been studied sufficiently to fix their wave-lengths; it seems likely that $A \div n$, may be a *bright* line. The line $A \div (n + 9a)$ is midway between Kirchhoff line 2869·7 = 430·37, and H = 397·16.

As in the solar system alternate planets, so in the Fraunhofer lines, alternate lines appear to obey the simplest law, the intermediate lines being governed by laws of mutual equilibrium. The figurate symmetry of the divisor differences for the alternate lines B, D, F, H ($1a$, $3a$, $6a$, $10a$), is specially noticeable, and suggestive of my equation between the principal planetary masses:

$$(\text{Neptune})^1 \times (\text{Uranus})^3 \times (\text{Jupiter})^6 \times (\text{Saturn})^{-10} = 1.$$

Haverford College, *Aug.* 23*d*, 1877.

SATELLITES OF MARS.

The following is an extract from the letter of Rear Admiral John Rodgers, Superintendent of the U. S. Naval Observatory at Washington, to the Secretary of the Navy, dated August 21st, 1877, announcing the discovery of two satellites of the planet Mars:

"The outer satellite of Mars was first observed by Professor Asaph Hall, U. S. N., on the night of the 11th of August, 1877. Cloudy weather prevented the certain recognition of its true character at that time. On August 16th it was again observed, and its motion was established by observation extending through an interval of two hours, during which the planet moved over thirty seconds of arc.

"The inner satellite was first observed on the night of August 17th, and was also discovered by Professor Hall.

"On Saturday, August 18th, the discoveries were telegraphed to Alvan Clark and sons, Cambridgeport, Mass., in order, that if the weather should be cloudy at Washington, they might confirm the existence of the satellites with the 26-inch telescope of Mr. McCormick, which is in their hands.

"The discovery was confirmed by Professor Pickering and his assistants, at Cambridge, Mass., and by the Messrs. Clark, at Cambridgeport.

"On August 19th the discovery was communicated to the Smithsonian Institution, by which it was announced to the American and European observatories * * * *."

Stability of English Iron-Clads.—It will be remembered that among the late experiments in naval architecture by the British Government, has been the construction of what are called citadel ships. These ships have the central portion of the hull, for about one-third its length, enclosed with armor of immense thickness, for the protection of the machinery, magazine and guns; the remaining portions being unarmored.

Of these, the *Inflexible*, supposed to be the most powerful vessel ever designed for the British navy, measures 320 ft. in length, 75 ft. in breadth at the water-line, with a mean draught of water of 24 ft. 5 in., and a total displacement of 11,407 tons. The central citadel is 110 ft. long by 75 ft. wide, and is protected with armor-plates of a total

thickness of 24 in. from 6 ft. below the water-line to 10 ft. above. Forward and aft of the citadel the hull of the vessel is entirely unprotected, except by a 3 in. armor deck 7 ft. below the water-line.

The *Inflexible* is now approaching completion, and two others on the same principle, the *Ajax* and *Agamemnon*, have been commenced, at an estimated cost of £500,000 each.

The London *Times*, of June 18th last, made the startling announcement that notwithstanding the 24 ins. of armor with which the *Inflexible* is protected, she will be capable of being sunk by shell-fire from an enemy, without her armor being even touched. This statement is based upon the alleged fact that the armored citadel does not provide the requisite stability to enable her to float upright when the unarmored ends are practically destroyed.

Mr. E. J. Reed, formerly chief constructor in the navy, and now a member of Parliament, repeated these charges in the House of Commons, in the evening of the same day, and stated that, from careful calculations made by himself, it was certain that the *Inflexible* would have no stability whatever, should the unarmored ends be destroyed.

Mr. Ward Hunt, First Lord of the Admiralty, denied these statements, and asserted most positively, on the strength of a recent inquiry into the matter, that she would have the requisite stability if the unarmored ends were completely perforated.

In the discussion which has since taken place, the stability of other armored vessels is called in question, and the position taken by Mr. Reed causes the more anxiety when it is remembered that just before the loss of the *Captain*, the Admiralty reported that she would be safe even with such damage as she was likely to receive in action, and yet she capsized while perfectly intact, and in an ordinary sea-way.

Such charges, involving great incompetency on the part of the Admiralty Board, were of too grave a character to be lightly passed over, and the subject was referred by the House of Commons to a committee of experts, whose report will be looked for with much interest by those interested in naval architecture. K.

Gout.—Dr. Th. Max. Sorel describes a successful treatment of hereditary gout, in his own case, by digitalis, quinine, and "Palmerston pills," with careful attention to exercise and diet.—*Les Mondes.* C.

Widening Delaware Avenue.—A commission, consisting of Messrs. Strickland Kneass, D. Hudson Shedaker, Robt. Briggs and Samuel L. Smedley, was appointed under a resolution of Councils of this city, on May 11th last, to make a survey and estimate the cost of widening Delaware Avenue, between Walnut and Vine Streets.

The object of this proposed widening was to make room for a line of railroad tracks connecting the lines of the Pennsylvania Railroad and those of the Reading Railroad, for the better accommodation of the traffic along that part of the Delaware river front.

The Commission has reported, and recommends that the width of Delaware Avenue be fixed at 80 ft. instead of 90 ft., as proposed by Councils, and that it shall be widened entirely on the eastern or river side, by appropriating 30 ft. of the heads of docks and shore ends of wharves.

The Commission believes that by a re-arrangement of some of the wharves or piers, and the extension of others to the Port Warden's line, the commerce now using this portion of the river front, with few exceptions, can be more fully provided for than at present.

They estimate that the cost of carrying out this plan, inclusive of any reasonable amount for property appropriated therefor, will, at present prices, not exceed $470,000. K.

A Finland Volcano.—Vast masses of smoke are reported as issuing from a mountain near the river Tara, and the snow in the neighborhood has been melted. The gradual elevation of the Bothnian shores has often been attributed to volcanic forces, and it is possible that they are finally seeking a vent. The region has, hitherto, been free from positive evidences of volcanic activity.—*Nature.* C.

Galvanic Crystallization.—The journal of the Russian Chemical and Physical Society, vol. ix, fas. 2, contains observations, by Shidlovsky, on the microscopical crystallization of various metals under the influence of a galvanic current. The dondritric agglomerations of crystals form very speedily; their branches spread out from the cathode to the anode plate, vibrate on reaching it, and collapse; this process is repeated till the space between the plates is filled with a spongy metallic mass. Each metal has a characteristic ramification. The crystallization does not appear when the anode is gold or platinum.—*Nature.* C.

Endowment of Research.—The British Government, on the recommendation of the Royal Society, has appropriated £3935 in aid of scientific research during the present year. The largest appropriations are of £300 each, to Prof. Parker, for morphological researches; to Dr. H. E. Armstrong, for researches into the Phenol Series and the effect of nitric acid on metals; and to W. Crookes, for researches connected with repulsion resulting from radiation.—*Nature.*
C.

The Jablochkoff Light.—In late Parisian experiments the kaolin bar, ignited by induction spark, was 8 centimetres long, and fully equal to 8 gas-burners. At the same time 3 electric candles were operated, each equaling about 40 gas-burners. The light is admirable for constancy and duration. The thickness of the kaolin plate is not more than 4 millimetres, and the quantity consumed is not more than 1 mm. per hour. The agitation of the candlestick does not interrupt the current. The graphite pencils are consumed at the rate of 8 centimetres per hour, but it is thought that any length required may be supplied by proper clockwork.—*Nature.* C.

Vegetable Ferment.—M. C. Kosmann cuts plants into small bits, which, when macerated in cold water, evaporated, and placed in thrice their volume of alcohol, give a white precipitate which is redissolved in a small quantity of water; after filtration it is precipitated anew in a triple volume of alcohol, and a ferment collected, which, when dry, is in the form of translucent amorphous grains, brownish, insipid, soluble in water, decomposable by boiling, and containing nitrogen. This ferment seems to be a general principle common to all plants, which plays an important part in the formation of proximate principles and their metamorphoses in the interior of the organized tissue. Kosmann regards it as a universal motor in the vegetable kingdom, which is developed at the same time as the cell, and which is probably secreted by the protoplasm. The chemical disturbance which arises on the decomposition of the ferment, and which is communicated to the starch, sugar, and glucosides, is not a fact peculiar to the ferment; the same thing occurs in the chemical action consequent upon the oxidation of iron in contact with air and water. Metallic iron, in oxidizing, converts starch into dextrine, glucose, or butyric acid; moist iron, oxidizing at the surface of water, stimulates the decomposition of starch.—*Les Mondes; Soc. de Chim. de Paris.* C.

Vacuum Brake.—The engineers of the French Northern Railway have made satisfactory experiments with the vacuum brake. MM. Sartiaux and Lartique have devised some ingenious arrangements for bringing it into automatic action, if any mistake is made respecting the crossings. Distressed passengers, who need help, can operate the brake instead of ringing a bell.—*Nature.* C.

An African Sea.—A writer in the *Scientific American* has lately estimated the amount of evaporation from the surface of the proposed Algerian Sea, the reduction of the ocean level, and the time required to fill the sea with a bed of salt. In his calculations he seems to have omitted any consideration of the amount of vapor that would be recondensed, over the sea or in the neighborhood of its banks, so as to find its way back into the reservoir from which it was drawn. The elements involved in the question are too numerous to be determined by a few ingenious numerical calculations, and the discussions in the French Academy show that there is no lack of able engineers and physicists, who are thoroughly competent and willing to look at the project in all its climatic and economical bearings, before any final decision is made.—*Comptes Rendus.* C.

Recomposition at Temperatures Higher than those of Dissociation.—It is well known that most bodies are decomposed under the influence of heat, and that if the temperature is high enough, their decomposition is complete. It seems natural to suppose, that above this temperature the compounds could not exist. But we have demonstrated, by the study of many compounds of silicium, that this conclusion is too general. 1. The sesquichloride of silicium, in particular, which is very stable at ordinary temperatures, begins to decompose at about 350° C.; its decomposition is complete at about 800°. It may be represented by the formula, $2\,Si_2\,Cl_3 = 3\,Si\,Cl_2 + Si$. The sesquichloride is formed again, if we place the products of its decomposition in a porcelain tube, at about 1200°: $3\,Si\,Cl_2 + Si = 2\,Si_2\,Cl_3$. The sesquichloride thus formed may be isolated by rapid cooling. If it is brought gradually into parts of the tube where the temperature does not exceed 800°, it is decomposed, and gives crystals of silicium which obstruct the tube. In this case we get bichloride, which boils at 58°, instead of sesquichloride, boiling at 146°. The sesquichloride of silicium presents, therefore, a great stability at a temperature much higher, as well as at a temperature much lower, than that which determines its

complete decomposition. We have observed similar phenomena with the protochloride and the subfluoride of silicium. These facts are not exceptional. M. Ditté has proved that selenhydric and tellurhydric acids, which are easily decomposed by heat, may be reproduced from their elements at a temperature higher than that of decomposition. 2. Platinum, heated to about 1400°, is neither fusible nor volatile in an atmosphere of nitrogen, oxygen or hydrogen; but if it is heated in a porcelain tube, and some bubbles of chlorine are admitted, small crystals of platinum are deposited in the parts of the tube which are at a lower temperature. The metal, therefore, acts as if it were volatile in the chlorine. This apparent volatilization is the result of the decomposition, by reduction of temperature, of a chloride of platinum formed at a very high temperature. To secure this chloride, we inserted in the porcelain tube a slender tube of glass, which was kept cool by a current of water. The compound, which was deposited on the lower part of the cold tube, proved, upon analysis, to be protochloride of platinum. 3. It is well known that ozone passes into the condition of ordinary oxygen at about 250° C., but if a tube containing oxygen, at a temperature of 1300° to 1400°, is traversed by a silver tube which is kept cool by a current of water, the surface of this tube is coated with binoxide of silver—insoluble in acetic acid; soluble, with liberation of gas, in ammonia. This is exactly what would have happened at the ordinary temperature, with oxygen ozonized by the known methods. If, by a tube of small diameter lodged in the cold tube, we extract the oxygen which has been ozonized by the heat and rapidly cooled, we can produce the discoloration of indigo and the characteristic variations of ozone; but if the ozonized oxygen is gradually cooled, it undergoes a complete decomposition, and we collect only ordinary oxygen. 4. Proust observed, that with the common blowpipe, silver gives a coating containing a little oxide of silver. H. Ste.-Claire Deville and Debray have shown that, by rapidly cooling the vapor of silver which is boiling in contact with the air, metallic silver may be obtained, mixed with a small quantity of oxide of silver. We may ask whether the oxide of silver, a body easily decomposed by heat, was really produced at a high temperature, or whether it resulted from a reaction between the cold silver and the hot ozonized oxygen. To settle the question, we vaporized silver in a porcelain tube, heated to 1400° and traversed by a tube which was well cooled by a current of water.

We thus collected, upon the cold tube, metallic silver mixed with a large proportion of protoxide of silver. In the preliminary experiments with the same tube, we proved that cold silver, in contact with very hot oxygen, gives only binoxide of silver, without a trace of protoxide. Therefore, protoxide of silver, although decomposed at a moderate temperature, may be produced at a very high temperature, like the other bodies that we have been studying.—MM. Troost and Hautefeuille, in *Comptes Rendus*, April 30. C.

Prizes of the French Academy.—The following prizes have been awarded:

1. Grand mathematical prize, to G. Darboux, for his discussion of the theory of singular solutions of equations for partial derivatives of the first order.

2. Extraordinary prize of six thousand francs, for the application of steam to the naval service, to A. Ledieu, for his publications upon ships of war and marine engines, from 1862 to 1876.

3. Poncelet prize to M. Kretz, for his aggregate works, and especially for the intelligent and devoted care which he has given to the publication of Poncelet's works.

4. Montyon mechanical prize, to M. Deprez, for his gravity- and inertia-integrator, and his pressure-indicator.

5. Dalmont prize, to M. Ribaucour, for his geometrical works, and especially for his manuscript memoir upon the theory of surfaces.

6. Lalande prize, to M. Palisa, for the discovery of nine new asteroids in 1874 and 1875, and the re-discovery, in 1876, of the asteroid Maia, which had been lost from observation for fifteen years.

7. Bordin prize, divided as follows: To M. Violle, 2000 francs; to M. Crova, 1000 francs; to M. Vicaire, 1000 francs; for their investigations relative to the temperature of the sun's surface.

8. Montyon statistical prize not awarded, but certificates of honorable mention to Dr. Bertillon, for his atlas, entitled "Demography of France, mortality according to age, sex, civil condition in each department, and for France entire;" to G. Heuzé, for his atlas, entitled "Agricultural France;" to Dr. G. Delaunay, for his manuscript memoir, entitled "Studies upon the civil condition of the commerce of Creil."

9. Jecker prize, to M. Cloez, for his researches relative to the oil of the seeds of *Elæococca vernicia*.

10. Barbier prize, to Prof. Planchon, for his work, in two volumes, upon Materia Medica. Gratuities were also awarded, of 1000 francs,

to MM. Gallois and Hardy, for their studies upon the bark of ***Erythrophlœum guineense;*** and of 500 francs, to Dr. Lamarre, for his work on the treatment of whooping cough.

11. Desmaziéres prize, to Ed. Bornet, for the "Collection of observations upon the algæ," by Bornet and Thuret, M. Thuret having died since the publication. A gratuity of 500 francs was also awarded to M. Müntz, for studies of mushrooms.

12. Thore prize, of 500 francs, to E. Oustalet, for his researches upon the tertiary fossil insects of France.

13. Bréant gratuities of 2000 francs, to Dr. Duboué, and 1000 francs to Dr. Stanski, for certain specified medical memoirs.

14. Montyon medical and surgical prizes: (1) To MM. Feltz and Ritter, for their clinical and experimental study upon the action of the bile, and of its principles introduced in the organism; (2) to Dr. Paquelin, for his new cautery; (3) to Prof. Perrin, for his treatise of practical ophthalmoscopy and optometry. Several certificates of honorable mention were also awarded.

15. Montyon prize in experimental physiology, to MM. Morat and Toussaint, for their work on the variation in the electric condition of the muscles, in the different forms of contraction. A medal of 500 francs was also awarded to M. Mialhe, for his labors in physiology and biologic chemistry.

16. Montyon prize, concerning unhealthy arts, of 2500 francs, to Prof. Melsens, for his successful employment of iodide of potassium as a specific in mercurial diseases.

17. Tremont prize, to Prof. Ch. André, for valuable experimental representations of the different phases in the transit of Venus.

18. Gegner prize, to M. Gaugain, for his scientific labors, memoirs and inventions, during twenty-five years, especially in electricity and magnetism.

19. Cuvier prize, to M. Fouqué, for his geological studies, in two series—the first having for their object the composition of volatile volcanic emanations; the second, the determination of the constituent minerals in ancient and modern lavas.

20. Delalande-Guerineau prize, to H. Filhol and Ch. Vélain; to the former, for his description of Campbell Island, and for his zoological, botanical and anthropological researches in Polynesia; to the latter, for his geological studies in Europe and in the Southern hemisphere.

21. Marchioness de Laplace prize, of a complete collection of Laplace's works, to Louis-Paul Henriot, first scholar of the Polytechnic School in the year 1876.—*Comptes Rendus*, April 23. C.

Geological Progress.—MM. Delesse and de Lapparent have prepared a valuable résumé of the geological works published during the years 1875 and 1876. Their work covers 184 closely-printed pages; we have room only for a few brief notes. The mean height of Europe, according to Leipoldt, is 296·838 metres; Humboldt's estimate was 205 m. The increase of temperature at given depths below the surface, is greatest in the equatorial regions. Prestwich has confirmed the views of Dana, Carpenter and Wyville-Thomson, relative to the distribution of ocean temperatures. The resistance of rocks to crushing is diminished (in some cases as much as 80 per cent.) by the absorption of water. The plasticity of surface rocks is intimately dependent on their argillaceous character; but at great depths, pressure, water and increased temperature, make all rocks plastic. Th. Hübener has demonstrated, in a lignite, the existence of a multitude of microscopic quartz crystals, which he attributes to a slow decomposition of infiltrated silicates by the humic acid. By treating a Vesuvian pumice, which seemed to be amorphous, with fluorhydric acid, Fonqué has extracted from it crystals of feldspar, pyroxene, amphibole, peridote, magnesian mica, and oxidized iron. He has also shown that the minute cavities of the pumice were decked with microscopic crystals of amphigene. The contest respecting the organic character of the *Eozoon* still continues; and even if its animal origin is granted, doubts are thrown on the assumed age of the Lawrentian formation, in which it is found. Owen has studied the bones of a curious carnivorous reptile, *Cynodrakon major*, from southern Africa. He assigns it, together with other similar reptiles from the same region, to a new order, *Theoriodontes*, having the dentition of carnivores. He thinks that their high organization cannot be explained by the hypotheses, either of Darwin or of Lamarck. Forests improve the soil much more rapidly than coppice-wood; the humus exhibits a very different composition from that of the rocks upon the surface of which it is formed. Experiments with Tresca's apparatus, seem to show that cleavage and lamination may be due to the same cause, and that the schistosity of gneiss may be no evidence of stratification.—*Ann. des Mines*, x, 438, *seq.* C.

ELECTRIC LIGHTING.

The following letter, addressed to the Secretary of the Franklin Institute, in reply to inquiries as to the success attending the use of the Electric Light at the Railway station mentioned, gives some interesting and valuable statistics.

Paris, 11*th July*, 1877.

Sir :—I take pleasure in sending you the information you desire, in regard to our experiments in electric lighting, made at the station of La Chapelle, Paris.

1. The source of electricity is the Gramme machine, of which I enclose a description; those which we have are of the type A. They require a force of 2·9 horse power (75 kgr.); in operation this force is somewhat reduced.

2. Up to this time we have used the regulator of M. Servin, with carbons of gas coke, having a square section, 0·009 m. on the side; the rods, 0·22 m. in length for the positive, and 0·11 m. for the negative, last four hours on the average. We have tried agglomerated carbons; they give a fine light, and are very regular in action, but the consumption is much more rapid, and we are waiting for their manufacture to be perfected. Many inventors are engaged upon them.

We have also tried a new regulator of M. Reynier, working more than 24 hours without change of carbons, but our experiments are not yet sufficient to give us any decided opinion on this new contrivance.

3. Our efforts have been chiefly directed towards obtaining a sufficient light, moderate, as uniform as possible, and not fatiguing the eyes of the employés; we have then sought to avoid the direct action of the luminous rays, and especially to use the reflected or diffused rays; for this purpose the lamp is enclosed in a large lantern, with glasses clouded by zinc white; this clouding is thick enough, and extends high enough, to prevent the voltaic arch being seen when the lantern is in place. We thus substitute, for the dazzling point furnished by the carbon pencils, a large shining body, the action of which cannot injure the retina.

In the halls, the rays which escape by the upper part of the lantern are sent, with all their intensity, towards the ceiling and the

top of the walls, which have been whitened, and serve as diffusing reflectors; we thus obtain, even when employing only a single lamp, placed in the middle of the hall, at a height of five metres, a general light, very suitable for the management and recognition of the packages, without troublesome shadows, and sufficient for a radius of 35 to 40 metres. In the open air, the lantern is closed at the top by a cap of tin plate, which serves much more as a cover than as a reflector. The walls of the lantern are formed of two glasses, with an interval of 0·01 m. between them, so that the outer glass is never heated enough to be broken by a sudden chill, and it protects the inner one.

A lamp, in these conditions, placed at a height of 6 or 7 metres, gives, in a radius of at least 60 to 80 metres, a light amply sufficient for the management of the cars.

The lanterns are prismatic, 0·45 m. to 0·50 m. on a side, and 1 m. to 1·10 m. in height. It would probably be much better if they were cylindric, or better still, pyramidal or inverted cones.

Our three lamps, working 10 hours per day, require:

Motive power,	6·85 f.
Mechanic, 10 h. @ ·50,	5·00 f.
Carbons,	4·50 f.
Interest and sinking fund, at 10 per cent. of the plant, having cost 23,000 f., say $\frac{2300}{365}$,	6·30 f.
Oil, repairs, cleaning,	1·00 f.
Total,	23·65 f.

one-third of which is 7·90 f. for ten hours' work, or ·79 f. per lamp per hour.

Preparation has been made for five lamps; in other words, the steam engine, and the building constructed expressly to shelter the machine, are sufficient to operate five Gramme machines. The expense would then be:

Motive power,	9·05 f.
Mechanic,	5·00 f.
Carbons,	7·50 f.
Care and cleaning,	1·50 f.
Interest and sinking fund at 10 per cent. of the capital, $\frac{2800}{365}$,	7·50 f.
Total,	30·55 f.

or about 0·60 f. per lamp per hour.

The sinking fund of 10 per cent. should be reduced to 8 per cent., on account of the buildings and the Gramme machines, which may be counted at 6 per cent. If we had not erected a building, the expense would have been lessened by more than 4000 f. The Gramme machines cost in Paris, 1500 f. apiece, the lamps 450 f., but I allow for two in the price of the plant. The lanterns, with their pullies, etc., cost 100 francs.

I beg you, Sir, to accept the assurance of my great respect.

For the Engineer-in-Chief,

A. SARTIAUX, *Asst. Eng.*

Book Notice.

THE ECONOMIC THEORY OF THE LOCATION OF RAILWAYS. By Arthur M. Wellington, C.E. 12 mo, pp. 230, cloth, $2.00. Railroad Gazette, N. Y., 1877.

This is an exceedingly practical and valuable work:

The error of most engineers has been to accept certain rules laid down by the earlier engineers as infallible, and apply them to all cases. Whereas each line of road presents problems to be solved by the data offered by its peculiar circumstances and conditions, and which may not be applicable to any other.

Time has been lost, capital wasted, and conclusions reached, and the efficiency of practical operation impaired by attempting to apply antiquated rules in regard to equation of distances, and curvatures, gradients, slopes, etc.

Mr. Wellington seems to have comprehended the true conditions, and has given sound, practical solutions of those economic problems on which the location of a line depends, and which perpetually affect its cost of operation. The book is needed. Had it appeared earlier, many engineering blunders might have been avoided, capital saved in construction, and dividends increased by reducing expense of operation.

We learn that the book will be used in the course of study in the department of civil engineering at the University of Pennsylvania.

H.

"THE MUSIC OF THE SPHERES."

By Pliny Earle Chase, LL. D.

More than three thousand years are supposed to have elapsed since Job heard the voice out of the whirlwind, discoursing of the time "when the morning stars sang together." It is nearly twenty-five hundred years since Pythagoras traveled into Egypt and the East, to be initiated into the mysteries of the Persian and the Chaldean Magi, the Indian Gymnosophists, and the priests of Amun-Ra. It was in these journeys, that he probably learned the doctrines of musical harmony, which became the groundwork of his own philosophy.

The disciples of Pythagoras claimed that he was the only mortal whom the gods had permitted to hear the music of the spheres. He taught that the orbits, in which the planets move, dividing the ether in their course, produced tones; and that the tones differed according to the size, velocity, and distance of the planets. In consequence of his notions of the supreme perfection of the universe, he necessarily believed that these relations were in concord, and produced the most perfect harmony.

About twenty-one hundred years after the death of Pythagoras, John Kepler made the first practical demonstration of the harmonies which Job had learned so long before. His most important results were embodied in the three famous laws, on which Newton's subsequent discoveries, and the whole modern theory of planetary motions, are founded. These laws may be thus expressed: 1. Every planet revolves in an ellipse, of which the sun occupies one of the foci. 2. The radius vector of any planet describes equal areas in equal times. 3. The squares of the times of planetary revolution are proportioned to the cubes of their mean distances from the sun. In announcing his discovery, he says: "Nothing can restrain me; I yield to the sacred frenzy. I dare ingenuously to confess, that I have stolen the golden vessels of the Egyptians, and will build of them a tabernacle to my God. If you pardon me, I rejoice; if you reproach me, I can endure it; the die is thrown. I write a book to be read; whether by the present, or future ages, it matters not. It can wait a century for a reader, if God Himself waited six thousand years for an observer."

Kepler also noticed the regularity in the increase of planetary intervals, in proceeding towards the outer limits of the solar system. Prof. Titius, of Wittenberg, expressed that regularity in the form of an empirical law, which Prof. Bode, of Berlin, subsequently simplified, and consequently published a suggestion, that a planet, which had not yet been discovered, might be found between Mars and Jupiter. This happy anticipation was verified on the first day of the nineteenth century, when Piazzi, at Palermo, discovered Ceres. Prof. Harding, of Göttingen, discovered Juno in 1804; Pallas and Vesta were both discovered by Dr. Olbers, of Bremen, in 1802 and 1807 respectively. In 1845, a new series of discoveries began, in the same belt, and now nearly 200 asteroids are known, whose mean distance is in striking accordance with harmonic prediction. The agreement of planetary positions with "Bode's Law" is shown in the following table:

	Mercury.	Venus.	Earth.	Mars.	Pallas.	Jupiter.	Saturn.	Uranus.	Neptune.
Theoretical . .	4	7	10	16	28	52	100	196	292
Observed . . .	3·9	7	10	16·4	27·7	52	100	191·8	296

The numbers in the lower line represent the mean aphelion of Mars and Saturn, the secular perihelion of Neptune, the mean perihelion of Venus, and the mean distances of the other planets. The law, as stated by Bode, provided for an indefinite continuance of the doubling intervals. Accordingly, when the discovery of Neptune confirmed the predictions of Adams and Leverrier, its distance was supposed to be 388, and when it was found to be only about three-fourths as great, Bode's law was said to have failed. But a glance at the table will show that it was merely modified, by the introduction of a new symmetry, for there are now two equal intervals at each extremity, the intervening intervals being uniformly doubled as we go outward, or halved as we go inward. The present indications, therefore, make it probable that Mercury and Neptune are the boundaries of proper planetary aggregation, although there may be asteroidal, cometary, fragmentary, and temporary clusters outside of each of those boundaries. This probability is strengthened by a variety of other considerations, one of the most important of which will be given in explaining the probable origin of this special harmony.

In 1849, Prof. Peirce communicated to the American Association for the Advancement of Science, the results of an investigation, made by Thomas Hill,[1] at Peirce's request, showing that the phyllotactic

[1] Subsequently President of Harvard University.

series, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, could be found in the orbital times of planets, as well as in the arrangement of buds and other organs of plant growth. Each term of this series, after the second, is formed by adding the numerators of the two preceding terms for a new numerator, and the denominators for a new denominator. Chauncey Wright, in *Runkle's Mathematical Monthly*, referred the phyllotactic law to nodes of extreme and mean ratio, which he called "the *distributive ratio*." In its application to plants, it distributes leaves most evenly around the stem, so as to provide for the most general participation in the beneficent influences of light, air, moisture, and vegetable nutriment; in its application to planets, it distributes all their mutual perturbations most evenly around the sun, so as to contribute to the stability of the system. These are, perhaps, the two most striking mathematical demonstrations that have ever been brought forward, to show the universal sway of Intelligence and Design.

The approximate phyllotactic ratios of orbital times are: Uranus $= \frac{1}{2}$ Neptune, Saturn $= \frac{1}{3}$ Uranus, Jupiter $= \frac{2}{5}$ Saturn, Asteroid $=$ $\frac{3}{8}$ Jupiter, Mars $= \frac{5}{13}$ Asteroid, Earth $= \frac{1}{2}$ Mars, Venus $= \frac{8}{13}$ Earth,[1] Mercury $= \frac{2}{5}$ Venus. By taking the mean distances which would represent these phyllotactic times, we find the following accordance:

	Mercury.	Venus.	Earth.	Mars.	Pallas.	Jupiter.	Saturn.	Uranus.	Neptune.
Theoretical. . .	3·7	6·7	9·3	14·8	28·	53·8	99·1	206·	327·1
Observed, . . .	3·9	6·7	9·3	15·2	27·7	54·3	100·	206·8	304·7

The numbers in the lower line represent the secular aphelia of Neptune and Uranus, the mean aphelia of Saturn and Jupiter, the secular perihelia of Earth and Venus, and the mean distances of Mars and Mercury. The upper numbers are those which would give the theoretical time-ratios, and would also yield a precise agreement between the theoretical and observed geometrical mean-times. The unit of comparison, both in this and in the previous table, is $\frac{1}{10}$ of Earth's mean distance from the Sun.

In 1850, Prof. Alexander presented to the American Association the first of a series of papers upon harmonies of the solar system. His final results were embodied in No. 280 of the quarto Smithsonian Contributions, published in March, 1875. He has shown that the relative mean distances of the largest planets, Jupiter and Saturn, are such as to have given them equal moments of inertia when the solar system was condensing from the primitive nebula, and that the

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[1] $\frac{8}{13} = 1 - \frac{5}{13}$.

consecutive ratios of other planetary distances can be closely represented by the $\frac{1}{2}$, the $\frac{3}{4}$, or the first power of the Jupiter-Saturn ratio. The following table shows the closeness of his approximations:

	Mercury.	Venus.	Earth.	Mars.	Pallas.	Jupiter.	Saturn.	Uranus.	Neptune.
Theoretical, . . .	3·9	7·3	9·9	15·7	28·8	52·3	94·5	195·6	300·6
Observed, ...	3·9	7·2	10·	15·2	27·7	52·	95·4	191·8	300·6

The numbers in the lower line all represent mean distances.

In 1871, Prof. Kirkwood sent a paper to the American Philosophical Society, in which he says[i]: "It is a very remarkable fact, in regard to the systems of both primary and secondary planets, that the periods, without any exception, have very simple relations of approximate commensurability." His theoretical arrangement of the planetary times differs from that of Prof. Peirce only at two points. Kirkwood adopts for Earth, $\frac{1}{2} \times \frac{1}{3}$ Jupiter, instead of $\frac{3}{8} \times \frac{5}{13}$ Jupiter, and for Venus, $\frac{3}{5}$ Earth, instead of $\frac{8}{13}$ Earth. Therefore, his ratios, as well as Peirce's, are all phyllotactic. Taking corresponding mean distances, as in Peirce's comparative table, and using an extreme instead of a mean asteroidal term, we get the following table:

	Mercury.	Venus.	Earth.	Mars.	Hygeia.	Jupiter.	Saturn.	Uranus.	Neptune.
Theoretical, ...	3·9	7·3	9·5	15·1	31·4	49·8	91·8	191·	303·1
Observed, ...	3·9	7·2	9·7	15·2	31·5	49·8	90·8	192·	303·4

The numbers in the lower line represent the mean aphelion of Neptune, the mean perihelia of Saturn, Jupiter and Earth, and the mean distances of the other planets.

In 1873, the writer communicated to the American Philosophical Society[ii] some comparisons between different planetary series, together with a new harmonic series of his own, and the following hypothetical explanation of Bode's law: "If we conceive a rotating nebulous mass with a slight equatorial nucleus of condensation, the line of particles between the surface and the centre will be influenced by tendencies to two different kinds of motion: first, as portions of a rotating mass, with velocities varying as the distance; second, as revolving particles, with velocities varying inversely as the square root of the distance. The first of these tendencies, combined with the moment of inertia, would urge such particles as were free to move, towards the linear centre of oscillation. If Mercury's mean distance be taken as the point of suspension, Uranus is situated

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[i] Proc. Soc. Phil. Amer., xii, 163.

[ii] Ibid, xiii, 470 *seq.*

approximately at Neptune's linear centre of oscillation, and each of the planets between Uranus and Venus is at the linear centre of oscillation between the next superior and the next inferior planet."

According to the calculations of Sir William Thomson, the precession of the equinoxes requires a theoretical rigidity in the Earth greater than that of steel. Such a rigidity is, of course, entirely opposed to anything that we know, as well as to everything that we can easily conceive, of the earth's internal structure. But the modern discoveries relative to the importance of æthereal undulations, suggest the possibility that the rigidity, which is theoretically requisite, may be found in those undulations. The wave velocity, in elastic media, varies as the square root of the quotient of the elasticity, by the density. The relative rigidity, therefore, if we measure it by the ratio of elasticity to density, is $(183,000 \div 3)^2 =$ 3,721,000,000 times as great in light as it is in steel. Laplace estimates the velocity of gravitating action as at least 100,000,000 times the velocity of light, and the relative rigidity of speedy and complete recovery from any perturbation would, therefore, be $3.721 \times (10)^{22}$ times as great in gravitating action as in steel.

The well-known experiment of the Chladni plates shows the tendency, in uniform vibrations, to drive material particles towards the nodes and away from the internodes. According to Fourier's theorem, "every periodic vibratory motion can always, and always in one manner, be regarded as the sum of a certain number of pendulum vibrations." If two clocks, ticking nearly synchronously, are so suspended that their vibrations can be mutually communicated, they will tend to absolute synchronism. Laplace explained, on this principle, the equations of commensurability in planetary revolutions, and Kirkwood, in the paper already referred to, proposes to extend the explanation to the time of primitive nebular rupture and planetary aggregation.

All music, as is well known, consists merely of "periodic vibratory motion" in an elastic medium, and is, therefore, subject to Fourier's theorem, as well as to all other laws of gravitating or central motion which are capable of producing or affecting periodicity. The most elastic media of which we know anything, are those through which the phenomena of light and gravitation are manifested, and we might reasonably anticipate, in such media, some striking displays of musical or harmonic arrangement.

When three numbers are such that the first is to the third, as the difference between the first and second is to the difference between the second and third, they are said to be in harmonical proportion; and a series of numbers, in continued harmonical proportion, constitutes a harmonical progression. This name has been adopted because, if a musical string be divided in harmonical proportion, the different parts will vibrate in unison. It will readily be seen, upon trial, that the reciprocals of any arithmetical progression constitute a harmonical progression; *e. g.*, $\frac{1}{1}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$; $\frac{2}{3}$, $\frac{2}{7}$, $\frac{2}{11}$, $\frac{2}{15}$; $\frac{c}{n-2a}$, $\frac{c}{n-a}$, $\frac{c}{n}$, $\frac{c}{n+a}$, $\frac{c}{n+2a}$: are all harmonical progressions.

The key-note of the solar system must evidently be determined by its two primary nodes—the Sun, which is about 750 times as large as all the planets, and Jupiter, which is about $2\frac{1}{2}$ times as great as the aggregate mass of all the remaining planets. In order that the other planets may vibrate in unison with their giant leader, and that there may be no discord in the continual hymn of our morning-star, it is desirable that the elastic æthereal strings, being all of similar density, should be of harmonic lengths.

Now Jupiter is so situated that it constitutes a node for each of the more remote planets, in the harmonical proportion of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{6}$. Its own harp-string is so subdivided, as to form planetary nodes in the harmonical progression, $\frac{1}{1}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$, etc., as shown in the following table:

Theoretical.	Observed.	Theoretical.	Observed.
$6\,c$ 298·68	Nep. *p*[i] 297·32	$\frac{1}{7}\,c$ 7·11	Ven. 7·23
$4\,c$ 199·12	Ura. *a* 200·44	$\frac{1}{9}\,c$ 5·53	V. M.[ii] 5·55
$2\,c$ 99·56	Sat. *a* 100·00	$\frac{1}{11}\,c$ 4·53	Mer. *a* 4·55
c 49·78	Jup. *p* 49·78	$\frac{1}{13}\,c$ 3·83	Mer. 3·87
$\frac{1}{3}\,c$ 16·59	Mars *a* 16·44	$\frac{1}{15}\,c$ 3·32	Mer. *p* 3·19
$\frac{1}{5}\,c$ 9·96	Earth 10·00	$\frac{1}{17}\,c$ 2·93	Mer. *s p* 2·97

[i] *p*, mean perihelion; *a*, mean aphelion; *s p*, secular perihelion.

[ii] Mean between mean distances of Venus and Mercury.

This is in curious analogy with Bernouilli's law of organ pipes—that if the pipe is closed at the end opposite the mouthpiece, we can, by gradually increasing the force of the air current, obtain the *uneven* harmonics of the primary tone. The key-note is sounded at Jupiter's mean perihelion, or the point of its mean maximum *vis viva.*

We may reasonably presume that the harmonic activity began even before the position of Jupiter was definitely marked out. If we start from the present mean boundary of the system, we find theoretical planetary positions at $\frac{2}{3}$, $\frac{2}{6}$, $[\frac{2}{9}]$, $\frac{2}{12}$ of Neptune's radius vector. But the immense mass of Jupiter seems to have drawn to itself the particles which might otherwise have collected at $[\frac{2}{9}]$, and to have nearly obliterated $\frac{7}{8}$ of the subsequent primitive nodes, so that the first planetary position of any importance, within Jupiter's orbit, is at $\frac{2}{36}$ instead of $\frac{2}{15}$ of the primitive radius, the present evidences of the earlier series being found at $\frac{2}{12}$, $\frac{2}{36}$, $\frac{2}{60}$, $\frac{2}{84}$ (or the equivalent $\frac{1}{1}$, $\frac{1}{3}$, $\frac{1}{5}$, $\frac{1}{7}$, if Jupiter's mean perihelion is taken as the unit.) In like manner, the combined action of the principal planetary masses seems to have modified this second series within the orbit of Venus, so that Mercury's mean position is a third harmonic to Jupiter and Venus, $\frac{1}{1}$, $\frac{1}{7}$, $\frac{1}{13}$. Taking the primitive harmonics as thus modified, we form the following table:

	Mercury.	Venus.	Earth.	Mars.	Juno.	Jupiter.	Saturn.	Uranus.	Neptune.
Theoretical,	3·85	7·15	10·01	16·69	26·74	50·06	100·11	200·23	300·34
Observed,	3·87	7·23	10·00	16·44	26·71	49·78	100·00	200·44	300·34

The asteroidal position, which is here taken, is the geometrical mean of the seven obliterated Neptunian harmonics.

In the following table, the errors of the closest planetary approximations, in each of the foregoing series, are given for the purpose of comparison. In the signs, which are prefixed to the percentages of error, + indicates an excess in the theoretical, — indicates an excess in the observed, value. The "Sum" is found by dividing the difference between the sums of the theoretical and observed values, by the sums of the theoretical values.

The "Range" is the sum, without regard to sign, of the greatest positive and the greatest negative error. The greatest range (·0602) is about half of the mean planetary range from mean perihelion to mean aphelion (·1178), and less than one-third of the mean range from secular perihelion to secular aphelion (·1868). "Mean I" is $\frac{1}{8}$ of the sum of the percentages of error, taken without regard

to sign. "Mean II" is the square root of $\frac{1}{8}$ of the sum of the squares of the percentages of error. The "Average" is $\frac{1}{8}$ of the algebraic sum of the percentages.

	Bode.	Peirce.	Alexander.	Kirkwood.	Chase.
Mercury, . .	+·0333	+·0144	+·0117	+·0144	—·0053
Venus, . . .	+·0029	·0000	+·0091	+·0001	—·0115
Earth, . . .	·0000	—·0071	—·0067	—·0079	+·0011
Mars, . . .	—·0269	+·0180	+·0309	+·0337	+·0148
Jupiter, . . .	—·0005	—·0045	+·0059	—·0045	+·0055
Saturn, . . .	·0000	+·0152	—·0099	+·0152	+·0011
Uranus, . . .	+·0217	—·0136	+·0191	—·0136	—·0011
Neptune, . .	—·0136	·0000	·0000	·0000	·0000
Sum, ...	+·0002	—·0018	+·0054	—·0015	+·0005
Range, . . .	·0602	·0336	·0408	·0416	·0263
Mean I, . .	·0124	·0091	·0117	·0112	·0051
Mean II, . .	·0177	·0113	·0147	·0152	·0072
Average, . .	+·0021	+·0028	+·0075	+·0047	+·0006

Although the evidence, as here presented, of phyllotactic and harmonic influences is the most satisfactory, it seems impossible to doubt the efficacy of each of the tendencies upon which the other series are grounded. The superior importance, in human affairs, of the superintending and controlling Will, is almost universally acknowledged, and the most successful investigators have instinctively sought for evidences of an analogous, although infinitely higher, control, in the material universe. It should, therefore, be no cause for surprise, if we find that the most rigid mathematical tests point, from the very earliest moment of incipient nebular condensation, to such beneficent and æsthetic contrivance as, in the words of Newton, "could only proceed from the counsel and dominion of an intelligent and powerful Being." When we recognize the great truth, so tersely enunciated by Oersted, that "the laws of Nature are the thoughts of God," we may be prepared to find those thoughts expressed in manifold ways, modified by mutual interaction, but all working harmoniously together in developing the eternal designs of infinite Wisdom. As nebular condensation proceeded, through its various stages, from simple spherical aggregation to the formation of planetary nuclei, and to the ultimate gathering about those nuclei, of most of the outlying materials in our system, the laws of linear and spherical oscillatory inertia, and of cumulative cyclical action, must all have been operative. The record of their activity, as we have seen, may still be read in the measureless depths of space, where it was inscribed "in the beginning" by Him who "created the heavens and the earth."

Alsatian Report on the Centennial.—MM. Steinlen and Zuber presented to the Industrial Society of Mulhouse, a report in which they described the Philadelphia Exposition as more interesting and better organized than any that preceded it. Special thanks are given to the Franklin Institute and the American Association of Mining Engineers, for various courtesies: the calico factory of Joseph Lea and his associate, M. Eberhardt, is described as resembling a true Alsatian colony; the mechanical puddler of Messrs. W. Sellers & Co., their proposed continuous system of iron working, their establishment at Edge Moor, and their Philadelphia workshops, are all highly commended; the Corliss engine is praised for its general effect, in spite of some deficiencies of detail; the quality, finish, efficiency and moderate cost of the various steam engines, as well as of most of the machines, are extolled. Special notice is taken of the commercial iron and steel; sheet iron and steel; numerous samples of hammered work, showing the extreme density of the iron and steel, as well as the great skill of the smiths; imitation Russia iron; iron and steel rails; soft and tenacious castings, equal to the best Swedish; superior Bessemer fabrics, with particular encomiums on the rails, horse-shoes and wood-screws; hardware, including locks, padlocks, nails, saws, wrought and cast iron and enameled household utensils, edge tools, files, surgical instruments, cutlery, firearms; the general iron trade, second in importance only to that of England, a success which they attribute, in part, to the immense natural resources of the country in coal and minerals of excellent quality, partly to protective tariffs. They say: "We hold the American hardware as the most perfect in the world; free from the mannerisms as well as from the irrational and ungraceful forms which have been imposed upon us, by makers who are dealers rather than artisans."

In other departments they commend the fine displays of gold and silver ware, often displaying originality and grace, America ranking next after France. Austria and Russia, in taste and execution; superior telegraphic apparatus, and its common use in workshops, hotels, offices and private houses; excellent watches for ordinary use, the workmanship being such as soon to control the American market, and compete formidably with the European trade in other markets; furniture, of good shapes, solidly and well made, but of general bad

taste in the most costly styles; fine pianos; tissues of cotton, linen, wool and silk; very beautiful specimens of typography and engraving—the engraving of the paper-money being pronounced *splendide;* beautiful and solid bindings; crayons; metal pens of excellent workmanship; good, and often elegant, furnishings for the counting house; pretty stationery articles, rivaling the best in the world; fine writing papers of all descriptions; printing papers, as cheap as the European, in consequence of the partial substitution of straw and wood for rags; carriages, and their several parts. "The palace cars are the most beautiful and the most comfortable that we have ever seen; we cannot say as much of the greater number of those which are called first-class cars; they are certainly well built, but the passengers are cramped, badly seated, and they sometimes find themselves in too much democratic company."

They regard the general American custom of dispensing with jackets for cylinders and condensing apparatus, making no use of the escape steam except for winter heating, as ill-considered, remarking "that the Americans are not economists, in the sense of the more or less complete utilization of waste products, and the care to avoid loss: they prefer to seek new means of manufacture, or to render their present means more complete, more precise, more expeditious and more productive. A European metallurgist, with whom we traveled, and who had just been visiting some American mining works, expressed the opinion that many of the slags, from which they reaped no benefit, were at least as rich as the ores with which he was called to deal in Europe."

In Machinery Hall they notice the non-explosive boilers, hydraulic motors (especially the Geyelin turbines made by Wood); "Wood's castings, both such as are intended for turbines and the tubes for water conduits, are magnificent specimens of moulding;" shafting, hangers and pulleys; the general substitution of belting for gearing, and the great speed at which the belting is run; fine displays of blowing machines, motive powers for boats and portable fire-engines, very richly ornamented; locomotives, with steel fire boxes; machine tools, for metal and wood-working; the ingenious inventions from which "has resulted this fact, humiliating for us to acknowledge, that for most products destined for large consumption, the American fabric, in spite of labor which is paid twice or thrice what it brings elsewhere, is able to compete with the European in all markets, and

threatens to overpower it;" pumps and ventilators; forging machinery; the circular saw, with teeth of black diamonds, "working blocks of stone absolutely as if the material was wood;" spinning and weaving machinery, "carefully and solidly made;" drying machines, "of good construction;" "excellent calenders;" a new machine for stretching tissues; pantographs, for engraving printing rolls, "very well contrived and of an unexceptionable finish;" calender rolls of chilled iron, presenting admirable polish and finish, "due to a special contrivance created by the Americans, by means of which they are enabled to secure the action of hard metal cylinders with a perfection hitherto unknown;" printing presses; milling machines and apparatus; elevators; cutting, sewing, and embroidering machines; envelope machines; pin-making and setting machines; iron tubes, which "merit, in all respects, a special and most eulogistic mention," etc., etc.

In nearly all of the foregoing references, the American success is acknowledged to be quite equal to that of any other nation, and in many of them the palm of superiority is gracefully yielded. On some points, however, the criticism is unfavorable. While crediting our factories for their colossal dimensions and remarkable excellence of machinery, our lack of originality and our dependence on styles and designs stolen from France and Alsace, are sharply stated. The best educational exhibits were thought to be those from New England, but the neglect of careful attention to "little things," and particularly the frequent slovenliness of the writing, are regarded as grave defects. "Both in boys and girls the aptitudes for design, that language which speaks to the eyes, seem ordinary to the last degree. The needlework is careless and devoid of taste." Though the American belting is the best in the world, the tanning is imperfect, "The United States continue dependent upon France for skins and leather suited for the best shoemaking; the finest bootings are also of French production, and there is no reason to fear that it will soon be otherwise. We should state, in this connection, that the same thing is true for all objects of *grand luxe*—dresses, gloves, fine perfumery, toilet articles, furniture, bronzes, silver and plated ware, jewelry, mirrors, glassware, porcelain, cloths, tissues, carpets, paper-hangings, morocco work, and other goods designed for a select patronage."

After noticing the displays in Agricultural Hall, and commenting on the principal elements of production, such as raw materials, motive power, manual labor, prices current, rates of interest, and means of communication, the conclusion is drawn that our wonderful development is not factitious, and that we are perfectly fitted to compete with Europe. "Moreover, let us not forget that its commerce and its industry are governed by a people of devouring activity, eager for gain, even foolishly enterprising, and convinced to the last degree of its superiority over all other nations. This confidence, which has of late years lost no occasion to assert itself, has been again exalted by the spectacle which the Philadelphia Exposition offered to the Americans. They flocked thither in crowds, from all corners of the Republic, and returned to their homes prouder than ever of their title of Yankees. . . . The Americans owe this sentiment in great part to their professional education. Most of them have passed through a serious manual apprenticeship, and have learned to be good workmen before becoming masters. Coming thus into early contact with the realities and the details of their handicraft, they gain a surer eye, a better developed practical sense, and at the same time a greater confidence in themselves.

"Shadows are not wanting, however, in the tableau of the future industrial grandeur of the United States. The spirit of enterprise has its dangers, and may lead to formidable crises: the political situation of the country, more unsettled than elsewhere, will often injure the development of business; in fine, the want of good industrial traditions, the fruits of a long experience, and of extended commercial relations, will shackle, in some measure, the progress of American industry. But while these different causes may affect its prosperity, and diminish its benefits, they do not lessen the danger which results for us from the coming into line of a formidable competitor. . . . We not only bring you the firm conviction that the European importations into the United States are destined in a very near future, to embrace only articles of special manufacture, novelties of all kinds, and objects of luxury and taste; we are equally persuaded that, before long, the articles of large consumption, made in North America, will compete with ours in all foreign markets."—*Bulletin de la Soc. Indust.*, March–May, 1877. C.

AN ELEMENTARY DISCUSSION OF THE PRINCIPLE OF LEAST SQUARES.

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The Method of Least Squares is in constant use among engineers, for the adjustment of observations, but a simple and yet perfectly satisfactory proof of its main principle is still a desideratum. In this article, I wish to bring to notice a demonstration which has not yet found a place in English books, and which is far more simple and conclusive than the one usually given. I shall attempt, in writing it, to everywhere simplify and illustrate the reasoning of the proof, and to give enough of the fundamental principles of Probability to render the whole argument plain to those entirely unacquainted with the subject.

The proof alluded to is that of Dr. Hagen, who now, at a ripe old age, enjoys the honor of being one of the greatest hydraulic engineers of the century, and was first published at Berlin, in 1837, in his book entitled "Grundzüge der Wahrscheinlichkeitsrechnung." Although often used in subsequent German and French works, it received no attention from English mathematicians until 1865, when Prof. Tait re-discovered it in a greatly modified and much less satisfactory form, and published it in Vol. xxiv of the *Edinburgh Transactions*. This, and a paper by Mr. Kummell, of the U. S. Lake Survey, in *The Analyst*, 1876, Vol. iii, p. 133, are the only sources of information concerning it in the English language.[1] Mr. Kummell's discussion, although very abbreviated, and requiring in its readers a previous knowledge of the subject, was very welcome to mathematicians, and it contains one or two modifications of the German method of presentation, which considerably shorten the algebraic work.

Hagen's proof has, I think, but one difficulty, and that lies in the fundamental axiom or hypothesis upon which it is based. This difficulty is very slight compared with those in Gauss's or Laplace's proofs, while the mathematical work is vastly simpler. For the be-

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[1] See also, Price's *Infinitesimal Calculus* (London, 1865), Vol. ii, pp. 376–379.

ginner, it seems to me that Hagen's proof is decidedly the best of the thirteen[1] which have been offered.

I first proceed to give a few fundamental definitions relating to the subject:

DEFINITIONS.

When several observations, or sets of observations, are made to determine the magnitude of a quantity (for example, the length of a line), the results do not agree. All of these results cannot be correct, and each one of them can be regarded only as an approximation to the truth. The absolutely *true value* of the quantity in question we can never obtain, or, at least, be never sure that we have obtained; and, instead of it, we must accept and use a value derived from the combination of our observations which shall be the *most probable value*. The most probable value is that in which we have the greatest degree of confidence as being near to the true value.

The Method of Least Squares furnishes rules and processes for the determination of the most probable values of observed quantities. The reason of the name "Least Squares," will be plain in the sequel.

An error is the difference between the true value of a quantity and the value found by observation. If the true value exceeds an observed value, the error is called a positive one; but if it is less than an observed value, the error is called negative.

Constant errors are those which always, under the same circumstances, have the same values, and which, therefore, strictly speaking, are not errors, but the results of law. Such are: the effect of refraction upon a vertical angle, the effects of heat in changing the length of a measuring rod, the effect of incorrect graduation, the result of using an instrument not properly adjusted, etc. All such errors may be removed from the observations by a proper method of using the instrument, or by applying computed corrections to the measured results, and they *must* be so removed before the Method of Least Squares is used.

Accidental errors are those that remain after all constant ones have been eliminated from the observations. Such, for example, are the errors in leveling—arising from sudden expansions and contractions of the instrument, or from the effects of the wind, or those often observed in sighting across a river—arising from the anomalous and changing refraction of the atmosphere. More than all, however,

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[1] For brief notes on these thirteen proofs, see *The Analyst*, for March, 1877.

they arise from imperfections of our touch and sight, which render it impossible for us to handle our instruments with perfect delicacy, or estimate accurately small divisions of their graduation. These are the errors which the method of least squares discusses and adjusts. Being produced by many unknown causes, whose laws of action are also unknown, they can be discussed only by the laws of chance or probability. We must, then, as preliminary to our investigation, state and exemplify the first elements of the mathematical theory of Probability.

PRINCIPLES OF PROBABILITY.

The word *probability*, in mathematics, denotes a fraction between unity and zero, which indicates the degree of our mental confidence in the occurrence of an event. If the event is *certain* to happen, its probability is 1, if *impossible*, its probability is 0, and between these limits there may be every degree of belief and of probability. Thus, the probability that the sun will rise to-morrow morning, is about $\frac{2190001}{2190002}$, or almost a certainty; the probability of not drawing a prize, in a lottery of 250 tickets. 25 of which are prizes and the rest blanks, is $\frac{9}{10}$; the probability that head will be thrown in tossing a coin, is $\frac{1}{2}$; the probability of throwing an ace with a single die, in one trial, is $\frac{1}{6}$; and the probability that the dealer in a game of whist will have all the trumps, is $\frac{1}{158753389900}$, or almost an impossibility.

The probability of the happening of an event is a fraction whose denominator denotes the whole number of possible cases, and whose numerator denotes the number of cases in which the event may happen, all cases being supposed equally probable. Thus, in throwing a die, there are six possible cases, in five of which an ace will not be thrown, so the probability of not throwing an ace is $\frac{5}{6}$; if a pack of 52 cards contains 4 kings, and one card be drawn, the probability that it will be a king is $\frac{4}{52} = \frac{1}{13}$; if a bag contains 23 white and 2 black balls, the probability of drawing a white ball is $\frac{23}{25}$, and that of drawing a black ball is $\frac{2}{25}$.

The probability of the happening of an event, plus the probability of its failing, is unity. For it is *certain* that the event must either happen or fail. Thus, the probability of throwing an ace with a single die, in one trial, is $\frac{1}{6}$, the probability of not throwing an ace is $\frac{5}{6}$, and $\frac{1}{6} + \frac{5}{6} = 1$.

If an event may happen in different independent ways, the probability of its happening is the sum of the separate simple probabilities.

This follows immediately from the above definition of probability, and may be illustrated by the following examples: the probability of throwing either an ace or a deuce with a die, in one trial, is $\frac{1}{6}+\frac{1}{6}=\frac{1}{3}$; the probability of throwing either a head or a tail, in tossing a coin, is $\frac{1}{2}+\frac{1}{2}=1$; the probability of drawing a ball which is not white, from a bag containing 5 black, 3 red and 7 white balls, is $\frac{5}{15}+\frac{3}{15}=\frac{8}{15}$.

The probability of the happening of several independent events, is equal to the product of their separate simple probabilities. To prove this, let there be two bags, one containing 7 black and 9 white balls, and the other containing 4 black and 11 white balls, and, let us ask, what is the probability in drawing from both bags at once—that both balls drawn will be black? Since each ball in the first bag may form a pair with each one in the second, there are 16×15 possible ways of drawing two balls, and since each of the 7 black balls may form a pair with each of the 4 black balls, there are 7×4 cases favorable to the drawing of 2 black balls. Hence, by the definition above, the probability of drawing 2 black balls, is $\frac{7\times 4}{16\times 15}=\frac{7}{60}$. But the simple probability of drawing a black ball from the first bag, is $\frac{7}{16}$; that of drawing one from the second, is $\frac{4}{15}$, and $\frac{7}{16}\times\frac{4}{15}=\frac{7}{60}$. The rule is, therefore, proved.

As an illustration of the above principles, let us consider the following question: A solves three out of every four problems proposed, and B solves one out of every three; a certain problem being proposed, what is the probability that it will be solved if both try. By the definition, the simple probability that A will solve it, is $\frac{3}{4}$; that B will solve it, is $\frac{1}{3}$; that A will fail to solve it, is $\frac{1}{4}$; and that B will fail to solve it, is $\frac{2}{3}$. Now the problem may be solved in one of three independent ways, viz.:

1. When A solves and B fails.
2. When A solves and B solves.
3. When A fails and B solves.

Each of these ways is composed of two independent events, and the probability of each is found by the multiplication of the separate simple probabilities; or,

Probability of $1=\frac{3}{4}\times\frac{2}{3}=\frac{1}{2}$.
Probability of $2=\frac{3}{4}\times\frac{1}{3}=\frac{1}{4}$.
Probability of $3=\frac{1}{4}\times\frac{1}{3}=\frac{1}{12}$.

The sum of these, or $\frac{1}{2} + \frac{1}{4} + \frac{1}{12} = \frac{5}{6}$, is the probability sought. The same result may be found in another way, thus: the problem will not be solved if both fail; the probability of this is $\frac{1}{4} \times \frac{2}{3} = \frac{1}{6}$; but it is certain that they will either succeed or fail, hence $1 - \frac{1}{6} = \frac{5}{6}$, is the probability of succeeding.

The most probable event is that which has the greatest probability among all the probabilities of all the possible events. Thus, if 10 coins are thrown, the most probable case is that 5 of them will be heads and 5 tails; if 2 dice are thrown, the probability that the sum of the points will be 7, is greater than that for any other number; and, as we shall show in the sequel, the average of several direct measurements of equal precision, has a greater probability of being the true value than any other result that can be derived from those observations.

To show how this greatest probability (and hence, the most probable event) may be determined for simple cases, let us consider the following problem: Six dice are thrown at once; which is the most probable of the following cases?

1. Six aces turn up.
2. But five aces turn up.
3. But four aces turn up.
4. But three aces turn up.
5. But two aces turn up.
6. But one ace turns up.
7. No aces turn up.

Let p be the probability of throwing an ace with a single die in one trial, and q the probability of not throwing it. If 6 dice be thrown, the probability that all will be aces is that of the concurrence of 6 independent events, each of the simple probability p, or

$$p \cdot p \cdot p \cdot p \cdot p \cdot p = p^6.$$

The probability that *any assigned die* will not turn up ace, and that the other 5 will be aces, is $q \cdot p \cdot p \cdot p \cdot p \cdot p = p^5 q$: and, since there are 6 dice, this may happen in 6 ways, and hence,

$$6\, p^5 q$$

is the probability that only 5 will turn up aces. Similarly, the probability that *two assigned dice* will not be aces, and that the rest

will be aces, is $q \cdot q \cdot p \cdot p \cdot p \cdot p = p^4 q^2$; and, since this may happen in $\frac{1}{2} \cdot 6 \cdot 5 = 15$ ways,[1] we have

$$15\, p^4\, q^2$$

as the probability that only 4 aces will turn up. We see, then, that the successive terms of the binomial expansion,

$$(p+q)^6 = p^6 + 6\, p^5\, q + 15\, p^4\, q^2 + 20\, p^3\, q^3 + 15\, p^2\, q^4 + 6\, p\, q^5 + q^6,$$

represent the respective probabilities of the seven cases. Placing for p its value $\frac{1}{6}$, and for q its value $\frac{5}{6}$, we find:

1. Probability of six aces $= p^6 = \frac{1}{46656}$.
2. Probability of but five aces $= 6\, p^5\, q = \frac{30}{46656}$.
3. Probability of but four aces $= 15\, p^4\, q^2 = \frac{375}{46656}$.
4. Probability of but three aces $= 20\, p^3\, q^3 = \frac{2500}{46656}$.
5. Probability of but two aces $= 15\, p^2\, q^4 = \frac{9375}{46656}$.
6. Probability of but one ace $= 6\, p\, q^5 = \frac{18750}{46656}$.
7. Probability of no aces $= q^6 = \frac{15625}{46656}$.

From which we see that Case 6 is the most probable. The sum of the seven probabilities is unity, since one of the cases is certain to occur.

So in general, if p be the probability of the happening of an event, and q the probability of its failing, so that $p+q=1$, and if there be m such events, the terms of the binomial expansion,

$$(p+q)^m = p^m + m\, p^{m-1}\, q + \frac{m\,(m-1)}{1\,.\,2}\, p^{m-2}\, q^2 + \frac{m\,(m-1)\,(m-2)}{1\,.\,2\,.\,3.}\, p^{m-3}\, q^3 + \ldots$$

give the probabilities of the several cases, the first term being the probability that all the events will happen, the second the probability that $m-1$ will happen and 1 fail, the third the probability that $m-2$ will happen and 2 fail, and the $n+1$ term the probability that $m-n$ will happen and n fail. For example: If 5 coins are thrown, find the probability that all will be heads, that 4 will be heads and 1 a tail, etc. Here p, or the probability of throwing a head with a single coin in 1 trial, is $\frac{1}{2}$; q is also $\frac{1}{2}$, and m is equal to 5. Substituting these in the binomial formula, we find

$$\tfrac{1}{32},\ \tfrac{5}{32},\ \tfrac{10}{32},\ \tfrac{10}{32},\ \tfrac{5}{32} \text{ and } \tfrac{1}{32},$$

as the respective probabilities of the six possible cases.

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[1] See the Theory of Combinations and Permutations in any algebra.

THE PROBABILITY OF ERROR.

If a person accustomed to the use of the rifle shoots 500 times at a target, all the bullets will not hit the central bull's-eye, and some, perhaps, will not even hit the target. The deviation of each bullet from the centre of the target is an *error*, and, furthermore, an accidental error, produced by changes in the wind, imperfections in the sight of the marksman, etc.; for all constant errors, such as the effect of gravitation, are assumed to be eliminated in the sighting of the rifle. An examination of the bullet marks on the target shows us, however, that these accidental errors are arranged around the central point in a very regular and symmetrical manner. First, we observe that small errors, or deviations from the centre, are more frequent than large ones; secondly, that they are arranged symmetrically around the centre, so that at equal distances above, below and on each side of that centre, the number of marks in a square inch is approximately the same; and thirdly, we recognize the fact that very large errors (such, for instance, as a deviation of half a mile from the centre) do not occur. Further, the greater the skill of the marksman, the more closely will his bullets be grouped around the centre.

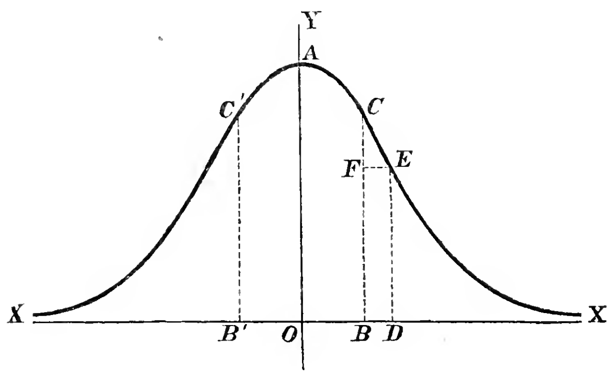
Again, suppose an engineer to measure an angle 500 times with equal care, the readings will disagree, the differences between the true value of the angle and each of his measurements will be an error; and we recognize that, like those of the marksmen, they will be subject to three laws: First, small errors will be more frequent than large ones; second, errors in excess and deficiency will be equally numerous; and third, very large errors, like those of 2°, do not occur.

In any set of carefully made observations, then, the probability of a small error is greater than that of a large one, the probability of a positive error is the same as that of an equal negative error, and the probability of a very large error is zero. Thus the probability of an error is a *function* of the error, so that if x represents any error, and y its probability, we may write

$$y = f(x),$$

an equation stating that y is a function of x, that is, that y is in some way related to x and dependent upon x for its value.

If we regard x as an abscissa, and y as the corresponding ordinate, the equation $y = f(x)$ represents a curve, which must be of such form as to agree with the three laws adopted above, viz., its maximum ordinate $O\,A$ must correspond to the error zero; it must be symmetrical with respect to the axis of Y, so that if $O\,B = O\,B'$, $B\,C$ will equal $B'\,C'$; as x increases numerically, y must rapidly decrease, and when x becomes very large, y must be very small. The figure represents such a curve, $O\,B$ and $O\,D$ being two positive errors, having the respective probabilities $B\,C$ and $D\,E$, and $O\,B'$ being a negative error whose probability is $B'\,C'$. The particular dimensions of the curve will depend upon the precision of the observations, and each set of measurements will have a distinct curve of its own, whose general form, however, must be as shown in the figure.



If now we can find the value of $\varphi(x)$ so that the probability y of any error x is given directly in terms of x, we shall have the equation of the curve which represents the law of probability of error. This equation we now proceed to deduce.

HAGEN'S DEDUCTION OF THE LAW OF ERROR.

The demonstration of Hagen is based upon the following axiom or hypothesis: *An accidental error of observation results from the combination of a very large number of small elementary errors, which are all equal, and each of which is equally likely to be positive or negative.* Thus, suppose that by several observations with a leveling instrument the difference of level between two points has been determined. This value is greater or less than the *true* difference of level by a small error x. This error x is the result of numerous causes, acting at

every observation; the instrument is not perfectly level, the wind shakes it, the sun's heat expands one side of it, the level's bubbles are not accurately made, the spider lines are not in perfect adjustment, the focus is not exactly set, the glass gives an indistinct definition, the eye of the observer is not in perfect order, there is irregular refraction due to the atmosphere, the man at the rod does not hold it vertical, the graduation of the rod is poor, the target is not properly clamped, the rod-man errs in taking the reading, etc. These causes may be subdivided into others, each of which produces a small elementary error Δx, and from our ignorance of the laws producing them we must consider that each Δx tends to make the observed result too large as often as it does too small, that is, each is equally likely to be positive or negative. The number of these elementary errors Δx is very great, and we designate it by m. If $\frac{1}{2}m$ are positive and $\frac{1}{2}m$ negative, the resulting error x will be 0; if more than $\frac{1}{2}m$ are $+$, the resulting error x will be positive.

Now it is evident that it is more probable that the number of positive elementary errors should be approximately equal to the number of negative ones than that either should be markedly in excess, and that the probability of the elementary errors being either all $+$ or all $-$ is exceedingly small. In the first case the actual error is small, and in the second large, and so the probabilities of small errors are the greatest, and the probability of a large error is practically zero. These correspond to the properties which we have shown the probability curve must possess.

Since by the axiom any elementary error Δx is equally likely to be positive or negative, the probability that Δx will be positive is $\frac{1}{2}$, and that it will be negative is also $\frac{1}{2}$. The probability that all of the m elementary errors will be positive, is hence $(\frac{1}{2})^m$, the probability that $m - 1$ will be positive and 1 negative is $m(\frac{1}{2})^{m-1}(\frac{1}{2})^1$, and the probabilities of all the respective cases will be given by the corresponding terms of the binomial formula. When all of the m elementary errors are positive, the resulting error of observation is $+ m . \Delta x$, when $m - 1$ are positive and 1 negative, the resulting error is $+ (m - 1)\,\Delta x - \Delta x$, or $+ (m - 2)\,\Delta x$. If $m - n$ elementary errors are $+$ and the remaining n are $-$, the resulting error is $+ (m - n)\,\Delta x - n . \Delta x$, or $+ (m - 2n)\,\Delta x$, and the probability of this particular combination is given by the $m + 1$th term of the

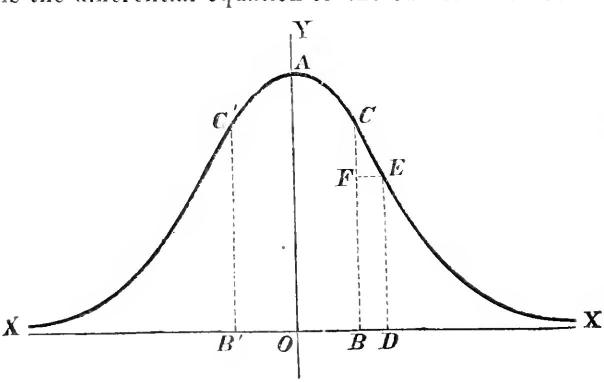
binomial expansion, p and q being each equal to $\frac{1}{2}$. We thus readily deduce the following table:

Elementary Errors Δx.	Resulting Error x.	Its Probability y.
If m are + and 0 are —	$m \, \Delta x$	$\left(\frac{1}{2}\right)^m$
If $m-1$ are + and 1 is —	$(m-2) \, \Delta x$	$m\left(\frac{1}{2}\right)^m$
If $m-2$ are + and 2 are —	$(m-4) \, \Delta x$	$\frac{m\,(m-1)}{1\,.\,2}\left(\frac{1}{2}\right)^m$
If $m-3$ are + and 3 are —	$(m-6) \, \Delta x$	$\frac{m\,(m-1)\,(m-2)}{1\,.\,2\,.\,3}\left(\frac{1}{2}\right)^m$
....	....	....
If $m-n$ are + and n are —	$(m-2n) \, \Delta x$	$\frac{m\,(m-1)\,(m-2)\,\ldots\ldots\,(m-n+1)}{1\,.\,2\,.\,3\,\ldots\ldots\,n}\left(\frac{1}{2}\right)^m$
If $m-n-1$ are + and $n+1$ are —	$(m-2n-2) \, \Delta x$	$\frac{m\,(m-1)\,(m-2)\,\ldots\ldots\,(m-n)}{1\,.\,2\,.\,3\,\ldots\ldots\,n+1}\left(\frac{1}{2}\right)^m$
....	....	....

In the curve $y = \varphi(x)$ let $O\,D$ be any error x, $D\,E$ its probability y, also let $O\,B = x'$ be an error less in magnitude, and $B\,C$ its corresponding probability y'. Then we see from the figure that

$$\text{limit } \frac{C\,F}{F\,E} = \text{limit } \frac{y - y'}{x - x'} = \frac{d\,y}{d\,x},$$

is the differential equation of the curve. To determine from this the equation giving the law of probability of error, we have simply to find $\frac{y - y'}{x - x'}$ in terms of y and x, pass to the limit, place it equal to the first differential coefficient $\frac{d\,y}{d\,x}$, and perform the integration.



Since x and x' represent any errors, x' being the less, we may take

$$x = (m - 2\,n)\,\Delta x \text{ and } x' = (m - 2\,n - 2)\,\Delta x,$$

then, by subtraction, we have

$$x - x' = 2\,\Delta x.$$

The probabilities corresponding to x and x', we have found to be

$$y = \frac{m\,(m-1)\,\ldots\ldots\,(m-n+1)}{1\,.\,2\,.\,3\,\ldots\ldots\,n}\,(\tfrac{1}{2})^m,$$

$$y' = \frac{m\,(m-1)\,\ldots\ldots\,(m-n)}{1\,.\,2\,.\,3\,\ldots\ldots\,n+1}\,(\tfrac{1}{2})^m.$$

From these we see that

$$y' = y\,\frac{m-n}{n+1}.$$

Subtracting both sides of this equation from y. gives

$$y - y' = y - y\,\frac{m-n}{n+1} = y\,\frac{2\,n - m + 1}{n+1},$$

and inserting in this the value of n, taken from the equation $x = (m - 2\,n)\,\Delta x$, it becomes

$$y - y' = y\,\frac{2\,\Delta x - 2\,x}{(m+2)\,\Delta x - x}.$$

Dividing this by the equation $x - x' = 2\,\Delta x$, member by member, we have

$$\frac{y - y'}{x - x'} = y\,\frac{2\,\Delta x - 2\,x}{(m-2)\,2\,\Delta x^2 - 2\,x\,\Delta x}.$$

When the elementary errors Δx are indefinitely small, the curve becomes continuous, and the limit of $\frac{y - y'}{x - x'}$ is reached; Δx then vanishes, in comparison with x, and

$$\text{limit}\,\frac{y - y'}{x - x'} = -\,\frac{2\,y\,x}{2\,(m\;\;2) + \Delta x^2}.$$

The quantity $(m+2)\,\Delta x^2$ requires particular attention; $m + 2$ is an indefinitely great number, and Δx^2 is an indefinitely small quantity of the same kind as x: the product $(m+2)\,\Delta x^2$ is hence a positive *constant*, which, for the present, we have no means of determining. Placing, then,

$$\frac{1}{2\,(m+2)\,\Delta x^2} = \text{a positive constant} = h^2,$$

we have,

$$\text{limit}\,\frac{y - y'}{x - x'} = -\,2\,h^2\,y\,x:$$

the differential equation is, hence,

$$\frac{d\,y}{d\,x} = -\,2\,h^2\,y\,x,$$

or,
$$\frac{d\,y}{y} = -\,2\,h^2\,x\,d\,x.$$

Integrating this, we have

$$\log y = -\,h^2\,x^2 + k,$$

in which k is the constant of integration, and the logarithm is taken in the Napierian system. Passing from logarithms to numbers, we obtain

$$y = e^{-\,h^2x^2 \,+\, k} = e^{-\,h^2x^2}\,e^{k},$$

in which e is the base of the Napierian system (the number 2·71828). Since e^{k} = a constant, this may be written

$$y = c\,e^{-\,h^2x^2},$$

and this is the equation of the probability curve, or the equation giving the law of probability of error.

DISCUSSION OF THE EQUATION.

Let us test this equation, and see whether it conforms to the conditions which we imposed upon the law $y = \varphi\,(x)$ at the beginning of our investigation.

In the equation,

$$y = c\,e^{-\,h^2x^2} = \frac{c}{e^{h^2x^2}},$$

y is the probability of the error x, and c and h are constants. Since the square of x only enters, equal positive and negative values of x will give equal values of y. Hence the curve is symmetrical with respect to the axis of Y, and this corresponds with the requirement that equal positive and negative errors should be equally probable. The greatest value of y will obtain when $e^{h^2x^2}$ is the smallest possible; this occurs when $x = 0$; y is then equal to c, and for all other values of x it is a fractional part of c; this agrees with the requirement that small errors should be more probable than large ones. As x increases numerically, $e^{h^2x^2}$ increases very rapidly, and when x is large, y is exceedingly small; and this agrees with the axiom that very large errors seldom occur. By computing the values of y for corresponding values of x, regarding c and h as unity, we may gain

a clear idea of the form of the curve. The following are a few such values:

For $x = 0{\cdot}0$	$y = 1{\cdot}$
$0{\cdot}2$	$0{\cdot}9608$
$0{\cdot}4$	$0{\cdot}8521$
$0{\cdot}6$	$0{\cdot}6977$
$0{\cdot}8$	$0{\cdot}5273$
$1{\cdot}0$	$0{\cdot}3679$
$1{\cdot}2$	$0{\cdot}2370$
$1{\cdot}4$	$0{\cdot}1409$
$1{\cdot}6$	$0{\cdot}0773$
$1{\cdot}8$	$0{\cdot}0392$
$2{\cdot}0$	$0{\cdot}0183$
......	......
$3{\cdot}0$	$0{\cdot}0001$
......	......
∞	$0{\cdot}$

From these values the above figure has been plotted, the vertical scale being double the horizontal. The curve crosses the axis of Y at right angles, and has the axis of X as asymptotes; the inflection point is at E, corresponding to $x = 0{\cdot}707$.

(It can be shown that the hypothesis of continuous errors adopted above, requires that c must be an extremely small fraction; the probability of the occurrence of any particular error being a fractional part of c, is, hence, exceedingly small. But the sum of all the possible values of y is equal to unity.)

The probability y' of any particular error x' will depend upon the constants c and h, and will be the larger the greater those constants are; c and h are hence related to the *precision* of the observations. The more carefully and precisely measurements are executed, the larger will be the values of c and h.

THE PRINCIPLE OF LEAST SQUARES.

Suppose, now, a number of observations be made to determine the values of certain quantities. However carefully the measurements be made, there will be disagreement in the results, and hence we can never be sure that any adjustment, which we may make, will give us the absolutely true values of the quantities. The most we can do, is to determine approximate results, which shall be the *most probable* values, and moreover be rendered most probable by the existence of the observations themselves.

The preceding principles of the probability of error afford a general rule for the determination of the most probable values of observed quantities. To deduce it in its simplest form, let us suppose that the observations are equally good, or made with the same degree of precision, then the constants c and h, which measure that precision, will be the same for all the observations. Let the errors of observation, which are the differences between the measurements and the corresponding *true* values, be denoted by x_1, x_2, x_3, etc.

Now, if x be any error, and y its probability, the law of error deduced above, gives the relation

$$y = c\, e^{-h^2x^2}.$$

Hence, for the errors actually committed, we have

$$\begin{array}{llll} \text{Probability of} & \text{the error} & x_1 = y_1 = c\, e^{-h^2x_1^2} & \\ \text{“} & \text{“} & x_2 = y_2 = c\, e^{-h^2x_2^2} & \\ \text{“} & \text{“} & x_3 = y_3 = c\, e^{-h^2x_3^2} & \\ & \text{etc.} & \quad\text{etc.} & \text{etc.} \end{array}$$

Now from the above principles the probability of committing the particular system of independent errors, x_1, x_2, x_3, etc., is the product of their respective simple probabilities, or

$$y_1 \cdot y_2 \cdot y_3 \cdot \text{etc.} = c\, e^{-h^2x_1^2} \cdot c\, e^{-h^2x_2^2} \cdot c\, e^{-h^2x_3^2} \cdot \text{etc.}$$

Designating this product by P, and reducing, we have

$$P = c\, c\, c \ldots . e^{-h^2(x_1^2 + x_2^2 + x_3^2 + \ldots .)}$$

as the expression for the probability of committing a particular system of errors.

What the true values of the measured quantities, or of the actual errors, are, we cannot hope to determine, and we must be content with finding their most probable values. Now the most probable system of errors is that which has the greatest probability among all the probabilities of all the possible systems. The most probable system, then, is that for which the product P is a *maximum*, and P in the above expression will be a maximum when the exponent of e is a maximum, that is, when

$$x_1^2 + x_2^2 + x_3^2 + x_4^2 + \text{etc.} = \text{a } minimum.$$

The errors found by this condition are called *residual* errors, to distinguish them from true errors. As these errors are functions of the observed quantities, the most probable system of errors must corre-

spond to the most probable system of values for the latter, and we have then the principle: *The most probable values of quantities, measured several times with equal care, are those which render the sum of the squares of the residual errors a* MINIMUM. Hence the term "Least Squares."

For example, suppose that a *single* quantity, whose true value is z, is directly measured n times with equal care, and let the measurements give the values $M_1, M_2, M_3, \ldots\ldots M_n$. Then the errors committed are

$$z - M_1 = x_1, \quad z - M_2 = x_2, \quad z - M_3 = x_3, \ldots\ldots z - M_n = x_n,$$

and the sum of their squares is

$$(z - M_1)^2 + (z - M_2)^2 + (z - M_3)^2 + \ldots\ldots + (z - M_n)^2,$$

and by the above principle this is to be made a minimum to give the most probable value of z. Applying the usual method for determining minima, we differentiate the expression thus,

$$2(z - M_1)\,dz + 2(z - M_2)\,dz + 2(z - M_3)\,dz + \ldots + 2(z - M_n)\,dz,$$

place it equal to zero, and divide by $2\,dz$, giving

$$(z - M_1) + (z - M_2) + (z - M_3) + \ldots\ldots + (z - M_n) = 0,$$

in which z represents the most probable, and not the true, value. Solving this equation we find

$$z = \frac{M_1 + M_2 + M_3 + \ldots\ldots + M_n}{n},$$

or, the most probable value of a quantity observed directly n times with equal care, is found by taking the arithmetical mean of the measurements.

If the observations are not of equal precision, the constants c and h are different for each measurement. For the observation M_1 we have c_1 and h_1, and the error x_1, for M_2 we have c_2 and h_2, and the error x_2, and so on. The product P here becomes

$$P = c_1\,c_2\,c_3 \ldots\, e^{-(h_1^2 x_1^2 + h_2^2 x_2^2 + h_3^2 x_3^2 + \ldots)},$$

and the most probable value is when it is a maximum, that is, when

$$h_1^2 x_1^2 + h_2^2 x_2^2 + h_3^2 x_3^2 + \ldots\ldots = \text{a } minimum.$$

The development of this principle to the deduction of rules for the adjustment of observations, together with the theory of the comparison of observations by means of their probable errors, constitutes the Method of Least Squares. About a hundred books have been written on this subject since 1805, the date of Legendre's discovery of the principle, but only three or four of them are in the English language.

STEAM BOILERS AND ENGINES FOR HIGH PRESSURES.[1]

By Mr. Loftus Perkins, of London.

The object of this paper is to bring before the Institution plans for generating high-pressure steam, say from 250 lbs. to 1000 lbs. per square inch, and working it with great expansion and perfect safety, in conjunction with simplicity and durability. Sixteen years ago the author, conjointly with Professor Williamson, read a paper on this subject at a meeting of this Institution in 1861. The engine and boiler then described have been in use ever since, and recently became the property of a gentleman who for several years has had another boiler and engine on the same system at work. The boiler and engine of 1861 are to be re-erected at the new works of the Sub-Wealden Gypsum Company, at Battle near Hastings, and are to form part of a steam plant consisting of three sets of boilers and engines, etc., on this system. Since 1861 many improvements have been effected, and are embodied in the engines recently constructed and illustrated in the accompanying diagrams.

In generating steam of the high pressure required to realize a fuller benefit of expansion, it has previously been found impossible to combine in the boiler great strength and safety with durability; if the former are secured, by reducing the internal dimensions and capacity of the boiler, the impurities passed in are fatal to the latter. In working a marine engine which was designed to use water distilled from sea-water, the author found that, although extreme care was taken to separate all the impurities from it before it was introduced into the boiler, the internal surfaces were in the course of time seriously injured. In the same manner, ordinary marine boilers using surface condensation have been injured when there has been an insufficient supply of sea-water to form a protecting scale on the exposed internal surfaces. This led the author to seek for a remedy, which he succeeded in discovering, and adopted with absolute success. This was the use of nothing but fresh water, or distilled fresh water in the boiler, used over and over again, without any admixture of sea-water or the products of sea-water, and this was easily accomplished, as the

[1] Paper read before the Institution of Mechanical Engineers.

machinery in question had been designed to avoid any leak whatever, and the amount of waste that did take place from glands, etc., was so small in quantity, that no practical inconvenience was found in providing the small supply of fresh water required to make good the waste that did occur.

The means taken to secure the soundness of all the joints and parts of the machinery were the same as those which had previously proved successful in the manufacture of the high-pressure heating apparatus which the author and his firm have been making for upwards of 45 years, and which has continued to work with the same water with which it was originally charged, without any destructive effect on the internal surfaces. Many sets of this heating apparatus have been working 40 years without decay; and some specimens of tubes from the boiler that was described in the former paper in 1861, which were cut out of this boiler for the Admiralty Boiler Committee in 1874, were found to be in such a remarkably good state of preservation that the committee made a special report on the system, which was laid before Parliament, and the specimens referred to are now shown on the table by the kind permission of the committee. The committee examined the condition of the boiler and cylinders of the engine at the writer's works, which were opened for the purpose, in the presence of the committee; and found the tubes of the boiler in a remarkably good state of preservation after having been in use nearly thirteen years, and the piston packing and valve rings made of the special metal were found in excellent condition after eighteen months' working without lubrication since last examined.

The possibility of using water which did not injure the internal surface of the boiler enabled the author to design the boiler on a system that combines maximum strength and safety. The horizontal tubes are $2\frac{1}{4}$ in. internal and 3 in. external diameter, excepting the steam collecting tube, which is 4 in. internal and $5\frac{1}{2}$ in. external diameter. The horizontal tubes are welded up at each end $\frac{1}{2}$ in. thick, and connected by small vertical tubes of $\frac{7}{8}$ in. internal and $1\frac{5}{16}$ in. external diameter. The firebox is formed of tubes bent into a rectangular shape placed $1\frac{3}{4}$ in. apart, and connected by numerous small vertical tubes $\frac{7}{8}$ in. internal diameter. The body of the boiler is made of a number of vertical sections, composed each of eleven tubes, connected at each end by a vertical one; these sections are connected at both

ends by a vertical tube to the top ring of the firebox, and by another to the steam collecting tube. The whole of the boiler is surrounded by a double casing of thin sheet iron, filled up with vegetable black to avoid loss of heat. Every tube is separately proved by hydraulic pressure to 4000 lbs. per square inch, and the boiler in its complete state to 2000 lbs., this pressure remaining in some hours without showing any signs of leakage. Experience of a very extensive character has proved that this construction of boiler can be worked safely, with great regularity, and without priming, and that the steam produced is remarkable for its freedom from moisture. The area through the vertical connecting tubes is found ample for allowing of the free escape of the steam, and for the prevention of injury from overheating of the tubes in contact with the flame. Injury arising from a prolonged stoppage of the feed supply is a casualty to which all boilers are liable, but with this construction of boiler the small capacity of the sections reduces to a minimum any danger arising from such injury, and facilitates rapidity of repair.

The engine has three cylinders: the first is a single-acting high-pressure cylinder, and the second also a single-acting cylinder, four times the capacity of the first; these two cylinders are bolted together in the same straight line, and have a common piston-rod. The third cylinder is double-acting, four times the capacity of the second, and its piston-rod is connected to a crank at right angles to the other crank.

Having safely generated steam of high pressure at say 350 lbs. per square inch, a serious difficulty has to be overcome in using it, from the high temperature affecting the lubrication of the pistons and packing of the glands. This difficulty the author has succeeded in overcoming by introducing the high-pressure steam into the upper end of the first cylinder, where there is no gland, and where the piston is formed so as to require no lubricating material. The steam is cut off at about half stroke in this cylinder, and when it is admitted for the return stroke into the bottom of the second cylinder, of four times the area, the temperature is so much reduced as to cause no difficulty when brought into contact with the piston-rod gland. From the bottom of the second cylinder the steam expands into the top of the same cylinder, which is of larger capacity than the bottom, and serves as a chamber, and is in direct communication with the valve box of the third cylinder; this last is double-acting, and is arranged to cut

off at about a quarter stroke, and at the termination of the stroke exhausts into the condenser, with a total expansion of about thirty-two times. All the cylinders are jacketed with wrought-iron tubes, which are cast in the metal, and supplied with steam direct from the boiler, the condensed water from the jackets being conveyed to the hot well. The whole of the cylinders and valve boxes, etc., are enclosed with a double case of thin sheet iron, filled in with vegetable black to prevent the escape of heat, and at the same time to maintain all the parts at a high temperature.

In working these high pressures with great expansion the ordinary mode of packing the pistons was found unsatisfactory, and to overcome the difficulty the compound piston was devised. The prevalent scoring and cutting of engine cylinders was effectually remedied by the discovery of the compound metal, of which the packing rings are made, which requires no lubricating material. Many cylinders fitted with piston rings made of this metal have been several years at work, and have been often examined, the cylinders showing no signs of wear, the wear takes place on the rings only, which may be easily and inexpensively renewed as required, and experience has proved that with these pistons, the longer an engine is worked the more perfect does the surface of the cylinders become, and the less wear results to the packing rings. This metal for piston packing rings is composed of 5 parts tin and 15 parts copper, and has since been used by several other makers for ordinary engines with great success. When this metal is used, no oil or grease is required to lubricate the cylinders—a great advantage, particularly where the engines are fitted with surface condensers.

The high-pressure piston in the steamers Atacama and Coquimbo of the Pacific Steam Navigation Company were fitted with these packing rings, and it was reported by the superintendent engineer that the cylinders, which were previously rough and slightly grooved, were in the course of two or three voyages, or about 10,000 miles' run, brought up to a beautiful smooth surface, and had since kept in capital order, giving no trouble whatever. After having been once brought up to a smooth working surface, the packing rings did not wear the cylinders; the wear of the rings was also very slight, and the friction greatly reduced, and one-third of the lubrication necessary for cast-iron rings was found sufficient. In the torpedo vessels made for the French Government, Messrs. Thornycroft found these

packing rings for the engine pistons a great advantage, as there was no chance of the cylinders being scored; and they were enabled to run the two hours' trial easily, at the high speed of about 430 revolutions per minute, without using any oil or grease in the cylinders. In an engine at the Dorking Grey Stone Lime Company's works, the manager reported, after $2\frac{1}{2}$ years' use of these packing rings for the piston, that they required no grease of any kind, and worked the cylinders to a polished face and needed no looking to until worn out; a set of rings lasted about 100 days, working at the usual high steam pressure of 400 lbs. per square inch.

The surface condenser used is constructed of a number of vertical tubes in such a manner as to be absolutely tight, so as to insure that the condensing water inside the tubes shall not mix with the water from the condensed steam outside them. The tubes are $\frac{7}{8}$ in. internal and $1\frac{5}{16}$ in. external diameter, welded up at the top end and fixed securely in a tube plate at the bottom. These tubes are fitted with internal tubes, open at both ends, which are fixed in a division plate at the bottom, in order to cause the condensing water to circulate to their extreme ends.

A small still, worked by a steam coil, is used to distil water for replenishing any small waste that may take place in the feed supply. A duplicate apparatus forms part of the ordinary equipment of a sea-going vessel, to furnish steam from sea-water, for blowing the steam whistle, cooking, supplying distilled water for use of passengers and crew, and for all other purposes where distilled water is required.

In designing the machinery described, provision is made for passing any waste steam from the safety valves, etc., into the surface condenser, and the great strength of the boilers allows a margin of 100 lbs. per square inch or more to exist between the load on the safety valves and the pressure required to work the engines. When this system is fully carried out in steamships, the author would deem it quite safe, and more than ample for making good the waste of water from all sources, to provide, beyond the water in the boilers, a supply of fresh water in the proportion of 10 gallons per 24 hours per 100 indicated horse power. As an instance of the practical feasibility of carrying out the system of machinery that has been described, it may be stated that a boiler containing only 300 gallons, and an engine working at 250 lbs. pressure and 250 indicated horse power, were worked night and day continuously thirteen days (one Sunday excepted) without

requiring any addition to make good the waste of working, nor at the end of the trial was there any appreciable difference in the water level of the boiler.

In the indicator diagrams exhibited, the two upper diagrams are taken from the working of a pair of marine engines on this plan of 70 nominal horse power, and the coal consumed averaged 1·62 lbs. per indicated horse power per hour. In this case there was no vacuum and no low-pressure cylinder, and the terminal pressure was 21 lbs. per square inch above the atmosphere; the boiler pressure was 300 lbs. per inch. With the addition of a low-pressure cylinder and a vacuum, the author considers it may safely be estimated that this system, properly carried out, will realize an average duty of one horse power for each pound of coal per hour.

A NEW METHOD OF COMPRESSING AIR.

By Jos. P. Frizell, C. E., Boston.

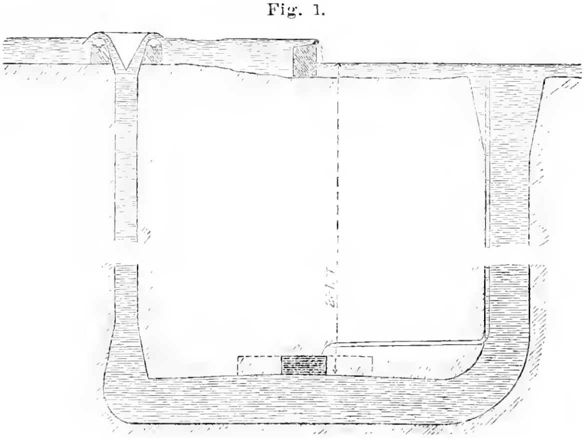
The memoir of M. Cornet in the June and July numbers of the Journal, is a very complete exposition of the difficulties attending the use of compressed air as a vehicle for the transmission of power. I am glad to avail myself of this memoir as an introduction to what follows, since a reference to it relieves me of the necessity of going into physical discussion in pointing out a method of compressing air entirely free from the sources of loss arising from the development of heat, as well as others inherent in the use of mechanism.

Bubbles of air rise in still water with a very moderate velocity; the velocity depends upon the size of the bubble, increasing as the latter increases, and this again depends upon the size of the orifice through which the air enters the water. From observations of my own, I find that bubbles issuing from an orifice of one-fourth of an inch diameter, do not rise faster than 15 inches per second in water of less than 20 feet depth. From depths of 50 feet the velocity is less than one foot per second. I assume in what follows that the average velocity in rising from depths of over 50 feet is one foot per second. This does not apply to great masses of air, such as rise when a diver is at work,

but to bubbles controlled in size by suitable orifices. Conversely, air drawn into a current of water which moves straight downwards with a velocity of more than 15 inches per second, will be carried down and subjected to a pressure corresponding to the depth attained. At the depth corresponding to the desired pressure, suppose the channel to take a horizontal direction. The air will here, in the course of a few seconds, rise to the top, and if it communicates at the summit with a suitable chamber, the air will enter it and accumulate under the desired pressure.

These considerations indicate the mode of transforming the power of a waterfall into compressed air, by the arrangement suggested in Figs. 1 and 2. The waterfall is supposed, as almost always occurs, to overlie a solid rock. At a point above the dam a vertical shaft is sunk to a depth corresponding to the pressure required. For a pressure of 100 lbs. per square inch the clear depth would be 231 feet. Thence a horizontal tunnel extends to a point below the dam, meeting another vertical shaft which reaches to the surface. The top of the tunnel is not exactly horizontal, but rises slightly from both ends toward the middle, at which point a chamber of sufficient capacity is excavated in the rock, whence the air is drawn off through a pipe. The whole forms thus an inverted siphon, through which the water flows with a velocity depending on the effective head. The length of the tunnel will be controlled by the necessity of placing the entrance to the chamber far enough from the descending branch to admit of the complete escape of the air bubbles.

Fig. 1.

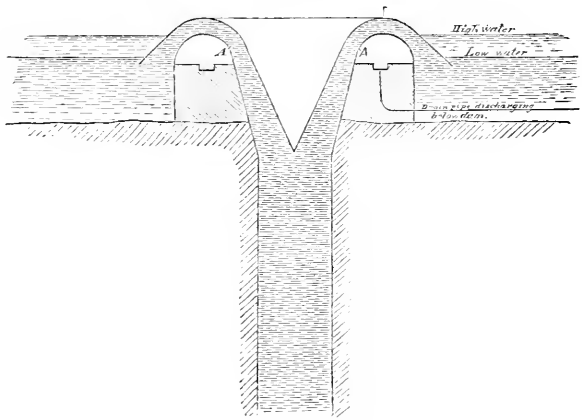


The effective head will depend on the quantity of air carried by the descending branch. This can be regulated at will, and furnishes the means of controlling the velocity.

Fig. 2 shows the method proposed for introducing the air bubbles into the descending column, though it is probable that a simpler method would disclose itself in the practical operation of the apparatus.

The entrance to the vertical shaft is surrounded by a bulkhead of masonry. Over this bulkhead the water is led in a covered channel whose bottom rises a little above the highest level of the water in the pond, forming a siphon. The arched space below the siphon and above the masonry, forms an accessible gallery, drained by a pipe which discharges below the dam. This gallery contains the cocks for regulating the admission of air. They are at *A* on the descending branch of the siphon channel, where its direction is nearly vertical. At this point the pressure within the siphon is less than that of the external air, and the latter will flow in through any opening; even should the external water rise as high as the top of the gallery, the internal pressure will be negative at *A*. This is evident from the fact that the flow does not take place by the direct action of gravity, but by the excess of the atmospheric pressure over that in the channel near the entrance. Were the entrance to the siphon closed by a gate, the pressure inside would be less than that of the atmosphere to a point as low as the surface of the water below the dam. It is apparent that the siphon channel extends entirely around the vertical shaft, except at one point, where it is interrupted by an entrance to the gallery. It is provided with a pump, worked by air from the chamber, to produce the vacuum when required, and remove, from time to time, the small quantity of air eliminated from the water. By allowing the air to enter the summit of the siphon, the flow may be suspended at will.

Fig. 2.



We have here a mode of compressing air entirely free from the difficulty which forms the subject of M. Cornet's memoir. The temperature of a minute bubble of air enclosed in a mass of water during the entire period of compression, which, in the case assumed, will last as much as 24 seconds, cannot rise to any serious extent. Let us endeavor to ascertain approximately what the losses of power would be by this method, or, by how much the power stored up in the form of compressed air would fall short of the absolute power expended. We will assume, as above, that the air is to be compressed to a tension of 100 lbs. per square inch above the atmosphere. The descending shaft 10 feet diameter, square in section, and lined smooth with plank. The remainder of the passage 20 feet diameter, unlined. The fall, 10 feet. The most important loss will be one analogous to what occurs in the slipping of a belt. The descending column may be likened to the tight side of a belt; the ascending, to the loose side. The upward movement of the air with reference to the water is analogous to the slipping of the belt with reference to its drum. This slip would be, on an average, about one foot per second, which suggests the propriety of employing a pretty high velocity in the descending shaft. A slip of one foot per second, in a belt moving three feet per second, involves a loss of 33 per cent. of the power, while the same slip, in a belt moving 10 feet per second, implies a loss of only 10 per cent.

The loss of head in a channel 230 feet long, 10 feet diameter, with a velocity of 10 feet per second, would be, according to Darcy and Bazin's experiments on channels lined with wood, 0·478 ft. Nearly the same result is obtained by Darcy's formula for cast iron pipes coated with bitumen. The loss in the remainder of the channel assumed, 400 feet long, 20 feet diameter, would be but 0·078 ft. The loss due to the several bends would be, by Weisbach's formula, 0·239 feet. It would appear necessary, at first sight, to allow the head due to a velocity of 10 feet per second in addition to the preceding, but this is not so. By a suitable enlargement of the discharging end of a submerged channel, a velocity can be obtained, much greater than that due the apparent head. The momentum of the water, as its velocity diminishes, is employed in diminishing the pressure of the ascending column, and thus increasing the effective head. Mr. Francis, in this manner, obtained a velocity of 10 feet per second

with an apparent head of only 0·3 feet. We will allow 0·4 feet for initial velocity. Putting the several losses together, we have:

Loss due to friction in descending shaft, . .	0·478 feet.
" " " remainder, . .	0·078 "
" " bends, ...	0·239 "
" " initial velocity, . . .	0·400 "
" " slip, being $\frac{1}{10}$ of the remaining head,	0·880 "
Total, ...	2·075 feet,

which is about 21 per cent.

Again, suppose the fall to be 3 feet, and other conditions the same as before. We should probably find it advisable to reduce the velocity to, say 5 feet per second in the descending shaft. The losses from friction, bends, etc., being nearly as the square of the velocity, would be about one-fourth of the above, viz.: . 0·30 feet.

Loss due to slip, $\frac{1}{5}$ of 2·7, ...	0·54 "
Total, ...	0·84 feet,

which is about 28 per cent.

A fall of 2 feet could be utilized with a loss of not over 40 per cent. For a fall higher than 10 feet we could expect a higher degree of economy. With a fall of 20 feet, for instance, the computed losses are 15·4 per cent. For practical purposes it would of course require extended calculations to find the most economical pressure of air and velocity of water for any given case.

We may affirm, then, that so far as our knowledge of hydraulics enables us to foresee the working of this apparatus, it will, on falls of 3 feet and upwards, convert 70 to 85 per cent. of the absolute power of the water into compressed air, at a tension of 100 lbs. per square inch. This transformation, by existing methods, involves the following losses:

1. An average loss of $\frac{1}{4}$ in the water-wheels.

2. A loss of at least $\frac{1}{8}$ in operating the mechanism of the air-compressor.

3. Of the power actually employed in compressing the air at 100 lbs., $\frac{1}{4}$ is lost, according to M. Cornet's calculations, in overcoming the resistance due to the development of heat. We have, therefore, for the part of the power actually realized in the form of compressed air, $\frac{3}{4}$ of $\frac{7}{8}$ of $\frac{3}{4} = \frac{63}{128}$, or a little less than $\frac{1}{2}$.

A comparison of the cost of this system with that of the water-wheels, canals, races, and mechanism, for accomplishing the same work, will show a result no less strikingly in its favor, not to mention its applicability to falls too low to be worth improving by the ordinary methods.

Its applicability to the much discussed problem of utilizing the tidal power will be at once apparent.

The loss of power due to the disappearance of heat during expansion in the air engine, attaches to this method, as to others. M. Cornet's method of dealing with this difficulty, by the injection of water in the form of spray, would undoubtedly be preferable in mines. In factories, a jet of high pressure steam would probably be preferable.

In factories, this difficulty is much more than counterbalanced by the advantage offered for the economical employment of heat. 1000 horse power in the form of compressed air, may be increased to 1400 by raising the temperature of the air 200 degrees F. The 400 additional horse power is secured at an expense not exceeding $\frac{1}{2}$ lb. oal per hour, per horse power.

Whooping Cough.—It is some years since Letzerich affirmed that whooping cough was due to a special fungus. The assertion has been lately confirmed by the researches of Tschamer. In the spittle of children who are suffering from the cough, there are little corpuscles, about the size of a pin's head, of a white or yellowish color, which pass through a series of characteristic changes, and which seem to be identical with fungi which are found on the peel of oranges, apples and some other fruits. By inoculating rabbits with these fruit fungi, and by causing men to inhale them, Tschamer produced convulsive coughs of many days' duration, with all the characteristics of whooping cough.—*Jahrb. f. Kinderheilcunde ; Les Mondes.* C.

Sensitive Thermometer.—An optician in Paris has constructed a new metallic thermometer. The expansion of a small sheet of platinized silver is amplified by a system of levers, and the motion communicated to a dial needle, as in Breguet's thermometer. It has been very satisfactorily tested in the new balloon, "Ville de Paris.' —*Nature.* C.

THE ELECTRIC REGISTER AND KOENIG'S TUNING FORKS.

By LeR. C. Cooley, Ph. D.

The application of electricity to register rapid vibrations, was first made in 1868.[i] In that year I succeeded in obtaining a direct registry of the vibrations for all the intervals of three successive octaves on a piano.[ii] The wire was made to open and close a battery circuit in which an electro-magnet was placed, whose armature carried a stile, and, responding to the alternate efforts of the electric pulses and an opposing spring, flew back and forth in unison with the vibrating wire, and left a dot for each vibration on a strip of moving paper.

But the motions of an armature are too sluggish to keep pace with vibrations beyond a certain degree of rapidity; hence, the electro-magnetic method was speedily abandoned, and an electro-chemical registry substituted. "The requirements are: first, a steady stream of electricity from a powerful battery; second, means by which the vibrating body may open and close this electric circuit; and third, a rapid motion of chemically-prepared paper, through which the electricity is passing." [iii]

In the instrument first constructed, a fine copper wire, forming one electrode of the battery, was rapidly drawn along over the surface of a strip of tin-foil forming the other. A strip of tissue paper moistened with acidulated water, lay upon the tin-foil; upon it the moving wire constantly pressed, and every electric pulse traversing the paper left a velvety black stain upon the foil beneath. The vibrations in any measured period of time were thus revealed in a series of dots easily counted and permanent in the highest degree; records made then, are as distinct to-day.

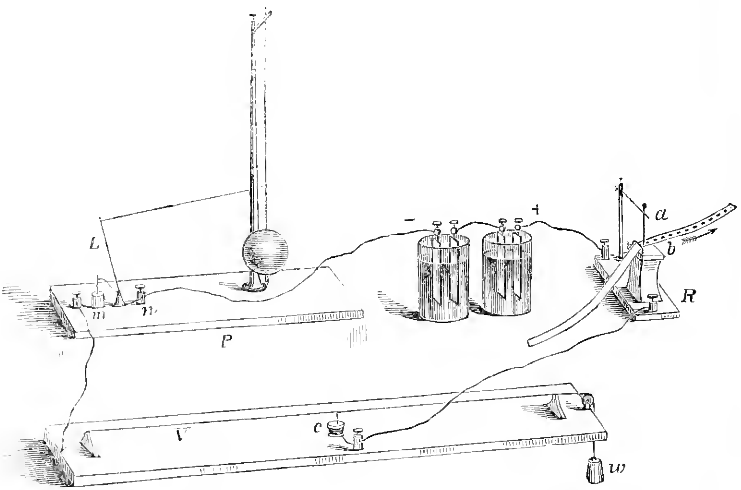
i *Proceedings of the Albany Institute*, Vol. i, p. 80. Journal of the Franklin Institute, Vol. lvii, p. 44.

ii Journal of the Franklin Institute, Vol. lvii, "Annual of Scientific Discovery," 1870, p. 162.

iii Cooley's "Text-Book of Natural Philosophy," p. 299. 1868.

With this instrument the laws of vibration were demonstrated by an almost unerring registry in several courses of lectures, yet certain difficulties in manipulation forbade the expectation that it would become generally useful. By changing the form of the apparatus and perfecting the method, however, the electro-chemical registry became, it seems to me, a matter of comparative ease, enabling one to study phenomena depending on rapidity of vibration, with the precision attained by actual count. Whenever the vibration is of amplitude sufficient to open and close an electric circuit, an *autograph* of

Fig. 1.



the vibrating body will be given in dots to be counted at leisure, and representing its rate within very narrow limits of error.

The accompanying cut represents the apparatus, arranged for the study of vibrating wires. The wire, *V*, a time measurer, *P*, and the register, *R*, are included in the same battery circuit. The wire is enabled to open and close the circuit by means of a fine steel needle, fixed to its middle point, beneath which is a cup of mercury, *c*, the surface of which is so nearly in contact with the point at rest, that every vibration of the wire will immerse it in the liquid metal. With good mercury, the needle being a substance not easily amalgamated and the surface of the mercury covered with alcohol to prevent oxidation, when once adjusted, little attention is needed afterward. Clean mercury may be substituted from time to time, and the needle may, if necessary, be cleaned by nitric acid.

For the measurement of time a pendulum is employed, which holds the circuit during the time of one beat. The arrangement for this purpose is represented at *P*. A slender fibre is fastened to the pendulum-rod, and thence reaches over to the upper end of a light bent lever, *L*. This lever moves freely, and is in conducting communication with a binding post, *n*. Beneath the lower end of the lever is a mercury cup, *m*, in metallic connection with another binding post. When the heavy pendulum is at rest, the weight of the lever keeps the fibre tense, and the mercury surface is so adjusted as to be exactly in contact with the point of the lever, a most vital adjustment, but one very easily made. It will be seen that the pendulum, when vibrating, must compel the lower end of the lever to be alternately in and out of the mercury during the exact time of one vibration.

The record of the vibrating wire is made in the register, *R*. A metallic point, *a*, presses upon a strip of chemically-prepared paper, which runs over a platinum surface, *b*. The pen and the platinum beneath, are each provided with a binding post, by which it can be made a part of the circuit. The paper may be drawn through by the hand of the operator, the more swiftly, as the vibrations are more rapid.

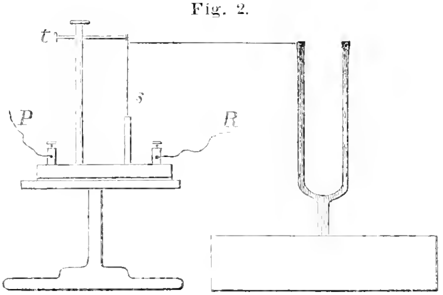
Let the circuit be continuously closed while the paper is in motion, and a continuous colored line will be traced by the pen, *a*, but let the wire vibrate, and electric pulses in unison with it will traverse the paper, leaving a series of dots instead. If the pendulum be at the same time in motion, the pulses can traverse the paper only while the lever, *L*, is in mercury, and hence a *group* of dots on the paper will represent the vibrations of the wire in the unit of time.

Various electrolytes may be used in the preparation of the paper. A strong solution of potassic iodide, mixed with a small proportion of starch, is very sensitive and easily managed. A strip of paper, strong, thin, with a smooth surface—strips cut from a sheet of book-paper of good quality, not over thick, are excellent—is *moistened* with this mixture. If too wet the dots will run together, if too dry the electricity will not traverse the paper: the strip should be moistened uniformly, but not wet. The record is written by a platinum pen, *a*, in dots of a reddish-brown color. Let it be at once washed in a stream of water, and the expected blue color takes the place of the brown; the fluid is at the same time washed from the paper, leaving the record in a condition to be more permanent.

Or, saturate the paper with a mixture of potassic ferrocyanide and nitric acid, made as follows: To four parts of a saturated cold solution of ferrocyanide, add one part of dilute nitric acid—one ounce acid to five of water. If the color of the mixture is decidedly blue, too much acid has been used; if no hint of blue appears, too little. With this fluid the pen, *a*, should be of copper, and the record consists of brownish-red dots of cupric ferrocyanide. Let the paper be washed to remove the excess of fluid, and the record may be preserved. This substance is less sensitive than the iodide, and not so pleasant to work with, but the dots are more permanent. Records made a year ago can be counted still.

In experiments with tuning forks, the vibrations may open and close the circuit by means of a solid break-circuit represented in Fig. 2. From the prong of the fork a silk fibre stretches across to a slender vertical spring, *s*, fixed at the lower end, while its upper end rests against the end of a set screw, *t*. The two surfaces in contact are platinized. The spring is slightly bent, and the set screw, pressing against its upper end, holds it in constant tension, and thus forbids it vibrating, except in unison with the fork. Every vibration of the prong is transmitted by the fibre, and compels the spring away from contact with the screw. Putting this break-circuit in place of the monocord, represented in Fig. 1, between the pendulum, *P*, and the register, *R*, the vibrations of the fork record themselves upon the moving paper.

Fig. 2.



Noticing that the accuracy of Koenig's tuning forks is questioned by Mr. Ellis (*Nature*, xvi, p. 85), I fancied that the testimony of this method would not be without interest. Seizing the earliest opportunity, therefore, I submitted the Ut_3 fork, bearing Koenig's monogram, to careful examination. The pendulum was accurately adjusted to hold the circuit one-half a second. The iodide-starch solution, with a battery of ten Bunsen's immersion cells, was used. Fifteen perfectly distinct and easily counted records were taken Every one of these autographs was found to consist of 128 dots, representing

128 complete vibrations per half second, 256 per second, or 512 according to the French notation.

But the instrument cannot record fractions of a vibration; on the other hand, no complete vibration can escape its registry. Evidently when the rate of the fork is any whole number of complete vibrations, that number must be recorded. Exactly 128 vibrations, for example, would yield invariably 128 dots; 129 would yield 129 dots invariably; but 128 and a fraction vibrations would yield 128 dots in some experiments, and 129 in others, and in this case the mean of several experiments would be a close approximation to the exact value of the fraction.

Now in the experiments with the Ut_3 fork the autograph *invariably* consisted of 128 dots, declaring the rate of the fork to be 256 complete vibrations per second, testifying to the exactness of Koenig's stamp.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. civ, page 119.]

Purification of Sulphuric Acid.—The sulphuric acid of commerce generally contains small quantities of lead, iron and arsenic, besides traces of selenium and thallium. It is only in some few of the arts that a pure acid is required on the large scale, *e. g.*, in the preparation of sulphate of soda free from iron for the plate glass manufacture. In most cases the iron and lead present in sulphuric acid do not interfere with its applications, and it can be freed from them, if needful, by simple distillation.

The removal of the arsenic is of greater importance, and for this purpose various methods have been proposed. H. A. Smith, in his

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[1] "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

work already quoted, has given detailed researches on the amount of arsenic acid in sulphur ores. He found in pyrites from:—

	Per Cent. Arsenic.
Spain, Tharsis,	1·651
Spain, Mason,	1·745
Belgium,	0·943
Westphalia,	1·878
Norway,	1·649
" rich in sulphur,	1·708

On roasting, a part of the arsenic remains in the burnt ore, a part is deposited in the flues leading to the chambers; a further portion arrives into the acid, and passes along with this into the various products prepared with its aid, and is finally found in the sulphur recovered from alkali waste. According to Smith there is present in:—

	Per Cent. Arsenic.
Norwegian pyrites (hard kind),	1·649
" " burnt,	0·469
Sulphuric acid,	1·051
Flue dust before entering chambers,	46·360
Chamber mud,	1·857
Hydrochloric acid,	0·691
Salt-cake,	0·029
Alkali waste after lixiviation,	0·442
Soda,	0·000
Regenerated sulphur,	0·700

As to the removal of arsenic from sulphuric acid, several important observations have been made in the last few years. Bussy and Buignet[1] have examined the customary methods for the removal of this impurity, and pronounce them insufficient. The precipitation of the arsenic by means of sulphureted hydrogen or barium sulphide, is not complete, and the use of these means involves a considerable dilution of the acid. If we attempt to purify an impure acid by distillation, we obtain, under certain circumstances, a product free from arsenic, but in most cases an arseniferous acid passes over. Bussy and Buignet have ascertained the conditions in which a pure acid is obtained. They found that sulphuric acid containing arsenic in the form of arsenic acid can be purified by distillation, but not such as contains arsenious acid. Arsenic acid remains entirely in the residue, whilst arsenious acid passes over. Hence, Bussy and Buignet recom-

[1] Bussy and Buignet, *Dingl. Pol. Journ.*, clxii, 454.

mend to treat the commercial acid, which generally contains both arsenious and arsenic acid, with nitric acid, in order to peroxidize the arsenious acid. The acid is then mixed with a little sulphate of ammonia, in order to destroy nitrous acid, and distilled.

Büchner[i] has modified his original process for the removal of arsenic, which consisted in heating the sulphuric acid with hydrochloric acid. He has perceived that arsenic, when present in crude sulphuric acid as arsenic acid, cannot be removed by hydrochloric acid. To convert arsenic acid into arsenious acid, the crude acid to be purified must either be first heated with charcoal and then treated with hydrochloric acid, or the heating with charcoal and the treatment with hydrochloric acid are conducted simultaneously. As experience proves that the acid in most cases contains arsenic acid, the treatment with charcoal is to be recommended in all cases.

Blondlot[ii] converts the arsenious acid into arsenic acid prior to distillation, not by nitric acid, but by manganese peroxide, or the manganate of potash.

Lyte[iii] proposes to heat the raw acid first to 110° in a bowl with $\frac{1}{4}$ to $\frac{1}{2}$ per cent. sulphuric acid, then to mix with chromate of potash, and finally to distil. The oxalic acid removes nitrous acid, and the chromic acid converts the arsenious acid into arsenic acid.

At Freiberg and Oker, sulphuric acid is purified by sulphureted hydrogen, and this process is particularly recommended, as the gas is not conducted into the liquid. The sulphuric acid is allowed to flow down a precipitating tower, fitted with prisms like a Gerstenhöfer furnace, but made of lead, and so arranged that an angle is always upwards and a side downwards. Into this tower enters from below a current of sulphureted hydrogen evolved from green pyrites and sulphuric acid. As the acid flows down in thin layers, the precipitation of the arsenic sulphide is very satisfactory.

Concentration of Sulphuric Acid.—The kinds of apparatus generally employed in sulphuric acid works for concentrating the chamber acid, are:—

1. Evaporation in leaden pans, standing upon cast-iron plates heated by the direct action of fire beneath the plates.

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i Bückner, *Bayer Kunst. u. Gewerb.*, 1864, 480.

ii Blondlot, *Comptes Rendus*, lviii, 76.

iii Lyte, *Chemical News*, x, 172.

2. The action of a reverberatory fire upon leaden pans, the edges of which have double sides and can be cooled by a current of water in order to prevent the lead from melting. Or the concentration is effected—
3. By steam.
4. By hot sulphurous acid.

In the application of the first-mentioned arrangement for concentration (open pans with direct fire), the author considers it advisable[i] to regulate the evaporation by the thermometer, as the lead is readily destroyed at a too elevated temperature.

At the commencement of the treatise just quoted, the author enters into an examination of the action of sulphuric acid upon lead, and states as the result of his observations that perfectly pure lead is more attacked during the concentration of sulphuric acid than a less pure metal. The same observation had been already made by Calvert and Johnson.[ii]

If the open pans employed in the evaporation are not made of too soft a lead, they last for a long time, at least if the concentration is conducted with due care.

Chandelon makes the judicious suggestion that the fire-gases from every arrangement for the concentration of sulphuric acid should be passed into a small separate chimney, since it is not possible to determine if a loss of acid is taking place when steam, hydrochloric acid gas, and the volatile products of the furnaces of a chemical works are all led into one large chimney.

The ordinary concentration in open pans is simple, and is still, therefore, principally in use, though not greatly to be recommended as far as repairs, consumption of fuel, and loss of acid are concerned.

The apparatus in which the flame plays directly over the surface of the acid was at one time widely used in England, and was first introduced into Germany at the Lüneburg Chemical Works. The furnaces last a long time without repairs, and consume little fuel, but are liable to the defect that an excessive temperature is often produced, when considerable quantities of sulphuric acid escape along with the products of combustion. On this account such furnaces

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[i] Hasenclever, *Ber. Chem. Ges.*, vi, 502.

[ii] Calvert and Johnson, *Comptes Rendus*, lvi, 140; *Dingl. Pol. Journ.*, 1863, 358.

have been abandoned in many places where they had been introduced.

The idea of concentrating sulphuric acid by the indirect action of steam, dates from the year 1865, and is due to Carlier, the manager of the Duisburg Chemical Works. After various experiments tried in this establishment, the evaporation, according to the report of F. Curtius, is conducted in wooden chests lined with lead, 4 metres in length and breadth. At the bottom of each chest are two leaden worms, each 45 metres in length, 3 centimetres in width inside, and 7 millimetres in thickness of metal. In order that the condensed water may flow off easily from the pipes, the bottom has the form of a blunted pyramid, the receptacle being 0·60 metre high in the middle, and only 0·3 at the ends. Both ends of the piping are in connection with the steam boiler, and can be shut off by means of cocks. The boiler is fixed lower than the concentration chests, which receive their supply of steam from a pipe leading from the dome. The pipes which allow the escape of the steam from the condensation chest, slope towards the steam space in the boiler, so as to permit a reflux of the condensed water into the latter. The action is intermittent. The chest is charged with acid at 1·5 sp. gr., and heated by steam till the sp. gr. rises to 1·7. The entire contents of the chest are then run into a wooden cistern lined with lead. In this reservoir there is a worm through which the chamber acid must pass on its way to the concentration chest, so that the latter is always fed with acid already warmed. The pressure of steam in the boiler amounts to three atmospheres, and an apparatus of the size given yields in twenty-four hours 5000 kilos. of acid at sp. gr. 1·7. The consumption of coal is 9 kilos. per every 100 kilos. of concentrated acid. The waste of lead amounts to 0·2 kilo. per ton of acid. The boiler only requires to be supplied with water to compensate for the escape through faulty joints. It is recommended to fence in the concentration chest with a wooden screen, to prevent the workmen from being injured by the hot acid scattered abroad if a steam pipe should burst.

Delplace observed at the Stolberg Works that the leaden steam pipes are principally attacked just where they plunge into the acid. The dust, which, even though slight, still gradually accumulates upon the pipes, causes by its capillary attraction the sulphuric acid to rise a few centimetres above the level of the liquid in the pan. This

acid is quickly concentrated by the steam, and thus rapidly occasions a strong corrosion of the lead. To meet this defect at the place where the pipe plunges into the acid, a leaden bell is blown on, opening upwards, and of rather larger diameter than the pipe itself. The outer leaden surface of the bell is still coated with a thin, damp layer of dust, but which is no longer heated by the steam.

Concentration by steam has been of late years widely adopted. No sulphuric acid is lost on account of the low temperature employed, and the process has the further advantages of cleanliness, of a very small consumption of coal, and of an important saving of labor.

(To be continued.)

Power of Electric Light.—Late experiments at St. Petersburg show that the power of the light may be increased by covering the carbon with a thin sheet of copper, and turning the cup towards the object to be illuminated. The most economical machine tried was that of Alteneck ,which, with a galvanized carbon of 10 mm. diameter, gave a maximum of 20,275, and a mean of 14,039 candles. The light was sufficient to make objects visible, for military purposes, at a distance of 3080 yards.—*Nature.* C.

Davyum: A New Metal.—Serge Kern announces his discovery in June last, of a new platinoid metal which he calls *davyum*, in honor of Sir Humphrey Davy. It is hard, silvery in lustre, malleable at red heat, readily soluble in aqua-regia and very feebly in boiling sulphuric acid, yielding a yellow precipitate with caustic potash. Sulphureted hydrogen, passed through a dilute solution of the chloride, yields a brown precipitate which becomes black upon drying. Potassic sulphocyanide, with the same solution, is colored red, and if the solution of davyum in KCyS is concentrated, a red precipitate is obtained. Sp. gr. 9·385 at 25° C. Kern thinks that in Mendelejeff's proposed classification of the elements, davyum is the hypothetical element placed between molybdenum and ruthenium, in which case its equivalent should be 100. It would then rank as the second confirmation of Mendelejeff's predictions, gallium having been the first. It is probably rare. The platiniferous sand does not contain more than ·00045 of davyum.—*Comptes Rendus.*

THE MISSISSIPPI RIVER IMPROVEMENTS.

Report of CAPTAIN JAS. B. EADS, to MR. JULIUS S. WALSH, President of the South Pass Jetty Company.

SIR:—I have the honor to submit the following report upon the improvement of the South Pass of the Mississippi river:

Head of Pass.—The depth on the shoal in the river obstructing the entrance to South Pass was 14 ft., or 15 ft. at low water, when the jetties at the mouth were begun. Until late in October, 1876, this shoal remained almost intact, while the channel between the jetties, 12 miles distant, had rapidly improved; and although 20 ft. of water could be carried out of the pass to sea, this was not available for commerce, because of the shoal obstructing the entrance at its head.

To create a channel through this shoal, an additional system of works was designed and constructed at the head of the pass, including two submerged mattress sills, 2 ft. thick, 70 ft. wide, and each over 3000 ft. long. These were sunk on the bottom of the river, across the entrance to South-west Pass, and Pass à l'Outre. The South Pass discharges only about one-tenth of the entire volume flowing out of the three passes, and these sills were designed to prevent any enlargement of the two great passes, and thus hasten the scouring action on the bottom of the new channel into South Pass. They are laid in deep water, and 30 ft. of depth can be carried into both passes over them. They are well ballasted with stone, and soundings show that the bottom of the river is now level with the tops of the sills. They will, therefore, be likely to remain permanently in their present position. These sills diminish the entrance into these two great passes about 7000 square feet each.

The works at the pass actually embrace and control the entire discharge of the Mississippi river, which is at this point one mile and three-quarters wide. They, therefore, surpass in magnitude any similar works in the world.. By them the wide funnel-shaped entrance to South Pass has been permanently converted into a narrower and

parallel one of 850 ft. in width. With the exception of the east dyke, they were commenced after the flood of 1876 had begun to subside, and in October had so far progressed as to control the flow into the pass. The use of dredge boats was then resorted to on the centre line between the parallel piers, within which the new channel has been formed, to hasten its development. These succeeded in cutting a narrow channel, of about 20 ft. in depth, through the shoal; but owing to the exceptionally low stage of the river at this time, the current was so feeble, that but little impression was made by the river through this dredged cut, and on the 1st of February it was not sufficiently widened to be available for vessels drawing over 15 ft., or 16 ft.

As the present depth of the bar at the mouth is no greater than it was when the works at the head were completed, nor indeed as great, the cause which interrupted the deepening that had previously proceeded with such remarkable regularity between the jetties, will be fully understood when the effect of the works at the head of the pass is considered.

Before the works there were built, the width, on the crest of the shoal, of the volume of water flowing into South Pass, measured transversely to the current, was 2400 ft. A concentration of this volume between parallel piers only 850 ft. apart, was relied on to secure the requisite depth of channel through the shoal, but this concentration (as will be seen by a chart of the works) could only be obtained by the erection of dams and piers, which greatly diminished the flow into the pass, and thus, for the time being, completely suspended the erosive action of the current between the jetties 12 miles below them.

During November, December, and January last, owing to the extremely low stage of the river, we were not justified in expecting scour through the works at the head of the pass, but were prepared to find deposits in the pass, and also between the jetties. To rob the pass, even temporarily, of so large a portion of its water, as was for the time barred out by our works at the head, necessarily reduced its current and caused considerable deposits to be thrown down during the time so much water was excluded.

Under these circumstances the rise in the river was looked for with considerable anxiety. It occurred about the 1st of February, and, as was expected, soon caused a rapid enlargement of the channel

through the shoal that had for so many years obstructed the entrance into the pass. Seventy thousand (70,000) cubic yards of sand were excavated by the current during the first seven days of February. Since that date, as the charts sent to you from time to time, show, the enlargement of the channel through the shoal has been going on with great rapidity, and upwards of 450,000 cubic yards have been excavated from it up to the present time.

The following table gives in detail the extent of its enlargement to May 23, 1877:

Date of Survey.	Least Width of 20 ft. channel. ft.	Least Width of 30 ft. channel. ft.
February 1, 1877,	30	
February 8, 1877,	250	
March 1, 1877,	360	
March 16, 1877,	370	
April 13, 1877,	415	30
May 6, 1877.	415	150
May 14, 1877,	420	170
May 23, 1877,	420	190

No detailed survey has been made of the head of the pass recently, but occasional soundings show continued enlargement. The works there will need no further expenditure this year, and the entire force employed in their construction has been discharged.

Although the February rise soon declined, and the next one did not come till the middle of March, the relief which the sudden enlargement of the entrance gave to the whole pass below, was readily observed in the channel between the jetties. The river water was heavily charged with sediment, but no new deposits were found in the jetty channel. During the month of February little or no change between the jetties occurred; the least depth on the bar was 20·04 ft., and the least width of the 20 ft. channel was 130 ft.

The Jetty Channel.—By the end of February the restoration of the full flow into the pass was felt in the jetty channel. Early in March a scour commenced in the upper portion of the jetty channel, and the enlargement of the channel very soon assumed remarkable dimensions. This enlargement has gradually extended down, and is now at a point 9000 ft. below the upper end of the east jetty. Its greatest depth on the 22d of June was 89 ft. at a point about one mile below the upper end of the jetty, and where the United States

Coast Survey map of 1875 shows a depth at that time of only 13 ft. The width of the 22 ft. channel through this 9000 ft. varies from 300 ft. to 500 ft. The 30 ft. channel is at one place 500 ft. wide. No scour occurs near either jetty, the deepening being confined to the central part of the channel.

To this extraordinary scour is to be attributed a slight deposit at the lower end of the jetties, which was observed to take place simultaneously with the scour in the upper portion of the channel. Careful estimates from a survey made in May, show, that since the end of March, 544,103 cubic yards had been scoured from between the jetties above station 80, while only 77,315 cubic yards of this amount have been deposited below that point near the sea ends of the jetties. The balance—466,788 cubic yards, or 86 per cent. of the whole scour—was completely transported into the gulf, and has been carried by the current far beyond the reach of our surveys.

Expressed in a more graphic form, the amount moved in 58 days from between the jetties, in a distance of 5000 ft. is equal to a mass of earth 900 ft. in length, 544 ft. in breadth, and 30 ft. high. This is equal to 9381 cubic yards removed each day.

When we consider that the volume of water, charged with this enormous quantity of sedimentary matter (in addition to what it had brought down from the river to the jetties), had, just before entering the gulf, to travel up a slope against the tides and winds, the fact, that only 14 per cent. of over half a million cubic yards of sand was dropped before it reached the end of the jetties, is one of the most encouraging features yet developed in connection with the jetty improvement.

On the 25th of April, the 22 ft. channel, 200 ft. wide, only extended uninterruptedly down between the jetties to station 68; or 6800 ft. Forty-eight days afterwards, June 12, it had been enlarged to 300 ft. in width, and then reached to station 90, or 2200 ft. further down than on April 25, thus averaging nearly 46 ft. per day in its progress to the sea. As the next payment from the United States will be due when a channel 22 ft. deep, by 200 ft. in width, is obtained through the jetties, the rate of enlargement since April 25, furnishes a basis on which to found a reasonable expectation as to the time when the next payment will be earned. The distance yet to be enlarged to 22 by 200 ft., and thus give a channel of that size through to deep water, was, on the 12th of June, 3000 ft. At

the rate of 46 ft. per day it should be through by the 16th of August. On the 20th of this month the 22 ft. channel had reached a point only 450 ft. from the deep water of the sea, but below station 90 it had only a width of 140 ft.

The Gulf in Front of South Pass.—A careful investigation was made last month of the condition of the gulf bottom, directly in front of the jetties, in order to ascertain what effect an almost uninterrupted scour of nearly two years' duration would produce. An area of 51·7 acres extending 2730 ft. seaward from the old crest of the bar, was covered with a large number of soundings accurately located by reference to the triangulation stations of the United States Coast Survey. The results of this examination were then compared with the chart of the coast survey of May, 1875, when the following results were ascertained.

The volume of water within this 51·7 acres, directly beyond the old crest of the bar, was:

In May, 1877, ...	2,387.849 cubic yards.
In May, 1875, . . .	1,970,849 " "

showing a gain of water within this area in front of the bar of 417,000 cubic yards, which is equivalent to an average increase of depth of very nearly 5 feet over the entire area investigated. In May, 1876, a similar examination had been made of the same area, showing an average gain in depth from May, 1875, to May, 1876, of 2·47 ft. From May, 1876, to May, 1877, the average gain in depth was 2·52 ft. These facts seem to clearly prove, that as the compact discharge from the jetties increases in depth by the erosion of the bar, the moving prism of river water compels the sea current, which is almost constantly passing under it on the outer slope of the bar in a direction transverse to the river's discharge, to scour out more room for itself under the outflowing volume from the jetties.

The apprehended re-formation of the bar in front of the jetties is shown by these facts to be unfounded; and it, together with the fear that the pass itself would deteriorate and fill up under the effect of the jetties, may be laid aside forever.

Condition of the Works.—The jetties are in excellent condition. The works have been constructed under the immediate supervision of Colonel James Andrews, who had, until the 1st of June, an unusually large force employed. The portions which had sunk by the compression of the mattresses owing to the deposition of sand and

other sedimentary matters in the mattress work, have been built up above high tide, entirely out to the sea ends of both jetties. The recommendations of the commission of the United States engineers, who, under orders of the Secretary of War, inspected the South Pass improvements last November, have been carefully observed, and the jetties have been well ballasted with stone, as suggested by them. The grant is being executed in perfect good faith, and the structures, as far as then completed, were acknowledged by this commission to be of the permanent and substantial character required by law.

The works have been thoroughly tested by some very severe storms since last December, but with the exception of the destruction of a few mattresses at the sea ends of the jetties, which had not been previously ballasted with stone, the damage done to them was very slight.

Some anxiety has been expressed as to the destructive effects of the teredo upon the willows and piles used in the construction of the works. Fears upon this point are groundless, for the reason that the teredo does not attack wood covered with sediment. The piles used in the work constitute no part of the permanent jetties. The core or interior of the jetties is formed of willow mattresses. These become completely filled with sediment so soon as the current ceases to pass through them. Their exposed surfaces are covered with stone ballast, which in like manner becomes filled with sediment, and this completely protects the willow work from the attack of the worm.

The various surveys referred to have been made under the supervision of Mr. E. L. Corthell, resident engineer, and Mr. Max E. Schmidt, chief assistant, aided by Mr. Webb and Mr. Morton, assistant engineers; to all of whom I am much indebted for prompt and intelligent co-operation.

Official Orders.—I take great pleasure in stating that the honorable Secretary of War has issued such orders as will permit the prompt delivery to me of the results of examinations and surveys made from time to time by Captain M. R. Brown, United States Engineer Corps, United States inspecting officer of the jetties. He has also directed Captain Brown to establish such regulations for the navigation of the pass, as will protect the tugs, barges, etc., of the jetty contractors from injury by the too rapid movement of the steamers using the pass.

Results.—Our works were begun two years ago in an unused outlet of the Mississippi river, and have necessarily disturbed the regimen governing the outflow to the sea of an enormous volume of water; but the theories upon which they were based have been fully vindicated by the results produced; and it is now manifest that entire and complete success will reward our labors. Among the prominent results developed by our operations, are the following:

1. The concentration of the water flowing across the sand bar at the mouth of the pass by the jetties, created a channel over 200 ft. wide, in no place less than 20 ft. deep, where only about 8 ft. previously existed.

2. The concentration of the water flowing over the shoal in the river, at the head of the pass, created a channel over 400 ft. wide, in no part of it less than 20 ft. deep, with the central part 30 ft. deep, where but 14 ft. to 15 ft. previously existed.

3. During the time in which a portion of the flow into the pass was interrupted by the works at its head, and the current consequently slackened, a temporary deposit took place in the pass and between the jetties.

4. The gradual restoration of the normal flow into the pass through the new channel at its head has already begun to enlarge the pass again, and has, since this restored flow commenced, removed from between the jetties within the past three months over half a million cubic yards of deposit, and given through more than half the length of the jetties a much larger and deeper channel than ever previously existed, the size of which is already throughout more than 2000 ft. 28 ft. by 300 ft., or that required to entitle us to the fifth payment from the United States, while many hundred feet of it exceed 30 ft. by 350 ft.

5. The gulf current athwart the jettied mouth of the pass effectually prevents the re-formation of the bar in advance of the jetties by deepening the outer slope of the bar, and sweeps away any such portion of the discharged sediment as the river current fails to carry to unknown distances seaward.

6. The Mississippi river at the head of the passes, where it has a width of over 9000 ft., is brought under complete control by our works, which are so designed as to enable us to increase or limit the discharge into our pass, if hereafter necessary, with but little additional outlay.

7. Finally, I may add with absolute certainty, that this entire system of works is now so far completed, that no financial difficulties can intervene to arrest the processes of nature, which are constantly operating to enlarge and perfect the desired channel through them.

JAS. B. EADS, Chief Engineer.

Report on the Depth of Water, at South Pass.—Capt. M. R. Brown, of the United States Engineers, stationed at the South Pass of the Mississippi, in his recent report on the progress of the work on Capt. Eads' Jetties, says that the expenditures upon this work during the last four or five months, have been much greater than during any other equal period since it was begun. The result is that there is now an uninterrupted channel entirely through the pass to the sea, $20\frac{6}{10}$ feet deep on an average at flood tide; that with the exception of one small mud lump, the twenty-two feet channel is 200 feet wide all the way through to within about 1200 feet of the sea. From this point, the twenty-two feet channel is narrower to within 145 feet of the sea. The lump mentioned, and the last 145 feet, are the only obstructions to prevent a vessel drawing twenty-two feet of water from passing through from the river to the gulf.

The River and Harbor bill of 1876, contains a proviso, that when there shall be an open channel with eighteen feet of water at mean tide, from the sea through the jetties to the port of New Orleans, no part of the $100,000 appropriated for dredging at the mouth of the Mississippi River shall be any longer available, and it is believed that the Secretary of War will soon order the work at the Southwest Pass to be suspended.

Relations of Light and Electrical Conductivity.—Dr. R. Börnstein obtains the following results: "The property of experiencing a diminished electrical resistance under the influence of luminous rays, is not confined to the metalloids selenium and tellurium, but belongs also to platinum, gold and silver, and in all probability to metals in general. The electrical current diminishes both the conductivity and the sensitiveness to light, of its conductor, and both of those, after cessation of the current, gradually acquire their former values.—*L., E. and D. Phil. Mag.*, June, 1877., Supp't. C.

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Franklin Institute.

HALL OF THE INSTITUTE, Sept. 19th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 185 members and 36 visitors.

The minutes of the last meeting (June 20th, 1877) were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the meeting held June 15th, last, a protest was entered against the proposed award of the Elliott Cresson Gold Medal to John Charleton, for his internal clamp coupling, for alleged want of originality, and that the question was referred back to the Committee on Science and the Arts, for report, where it is still pending.

The Actuary further reported that at the meeting of the Board held July 1st, the following resolution was adopted:

Resolved, That the Board of Managers recommend to the Institute the election of Mr. Frederick Ransome as an honorary member of the Institute.

Also, that since the meeting in June last, 20 persons have been elected members of the Institute; and at the last meeting the following donations to the Library were reported:

Sixth report upon the improvement of the South Pass of the Mississippi River, showing the condition of the work March 16th, 1877, by C. B. Comstock. From the Chief of Engineers.

Specifications and Drawings of U. S. patents, for February, 1877. From the Patent Office.

Die pflanzenwelt Norwegens, by Dr. F. C. Schübeler. Christiania, 1875.

Anden beretning om Ladegaardsoens hovedgaard. Andet hefte. Christiania, 1875. From the University of Christiania.

Memoirs of the geological survey of India, Vol. 12, Pts. 1 and 2.
Palæontologia Indica, Ser. X, 2, and X 1, 1. Also Records.
From Geological Survey of India.

Railroad Dom Pedro II, Department of traffic. Report for 1876. From Engineer F. P. Passos.

Report on the Mississippi jetties, by Jas. B. Eads, Chief Engineer, Aug. 18th, 1876. From G. Leverick.

Treatise on the rationale of compressing cotton, by S. H. Gilman. 2d Ed. New Orleans, 1877. From the Author.

New Encyclopædia of Chemistry, Pts. 21 to 25. From J. B. Lippincott & Co., Pubs.

Economic theory of the Location of Railways, by A. M. Wellington, C. E. From the Railroad Gazette, N. Y.

A Duplex partial earth test, by W. E. Agrton and John Perry.
Preliminary catalogue of the apparatus in the telegraph museum, by W. E. Agrton. 1877.
The importance of a general system of simultaneous observations of atmospheric electricity, by W. E. Agrton and John Perry. Yokohama, 1877.
The specific inductive capacity of gases, by John Perry and W. E. Agrton. Yokohama, 1877.
From the Imperial College of Engineering, Tokio, Japan.

The Secretary presented his Report, which embraced an illustrative description of the following subjects: Hancock's Inspirator, or Double Injector, for feeding steam boilers; J. G. Baker's Rotary

Circulating Pump (being a modification of his rotary pressure blower); the Articulating Telephone, invented by Prof. A. Graham Bell; and Brush's Magneto-Electric Machine.

An interesting discussion, participated in by a number of members, followed the presentation of the telephone. During the discussion the President called Vice-President Close to the chair, and the latter presided during the remainder of the meeting.

On motion of Mr. W. P. Tatham, seconded by the President, Dr. Rogers, Mr. Frederick Ransome, of London, was unanimously elected an honorary member of the Institute.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

BELL'S ARTICULATING TELEPHONE.

Extract from the Secretary's Report, at the Meeting of the Franklin Institute, Sept. 19th, 1877.

The principle upon which the articulating telephone primarily depends for its action, was among the discoveries of Faraday—that any disturbance of the magnetic condition of the core of an electro-magnet induces a current of electricity in the coil. It is also known that if a piece of iron be made to approach or recede from the pole of a permanent magnet, the magnetic condition of the latter will be changed. If, now, we use the pole of a bar-magnet as the core of a coil of insulated wire, we have but to make a piece of iron approach and recede from the pole of the magnet to produce a current of electricity in the coil.

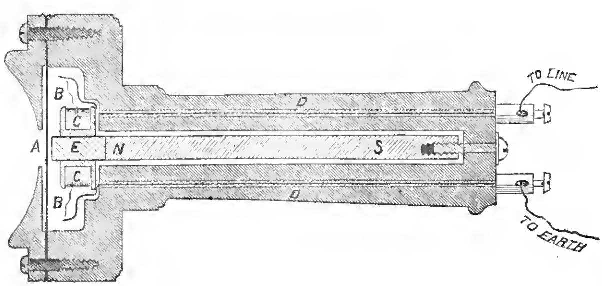
I will illustrate this with the aid of the galvanometer, which, as most of you are aware, is an instrument for measuring electrical currents, and consists of a small bar-magnet, called the needle, suspended within a coil of insulated wire, by means of a filament of silk, in such a manner as to swing easily. In order to make the movements of the needle apparent to the audience, there is attached to it a small mirror, from which is reflected that small spot of light on the screen.

The principle on which the galvanometer works, is that if a current of electricity is passed through the coil, the needle will tend to place

itself at right angles to the wire in the coil. As it is now placed, the needle is parallel with the wire. If, therefore, I place one pole of this bar-magnet within this coil of insulated wire, and connect the ends of the latter with the ends of the wire in the coil of the galvanometer, and approach this piece of iron near to the pole of the magnet, the needle of the galvanometer should be deflected in proportion to the strength of the current induced in the coil surrounding the magnet, and you should see the spot of light move toward one side of the screen. I now do this, and, you observe, that as I place this piece of metal quickly near to the magnet, the spot of light moves toward your left; and as I withdraw the iron quickly, the spot of light moves in the opposite direction, showing that the current is reversed.

All these facts were known before Prof. Bell commenced his investigations, but it remained for him to make the discovery—which enabled him to utilize these laws in the transmission of articulate speech—that if the piece of metal, intended to change the magnetic condition of the core of the coil, was made into a thin sheet and placed in front of it, and two such instruments were connected by a line of wire attached to one end of each coil, and the other ends connected to the ground, that sounds made in front of one of these plates would be reproduced by the other.

The manner in which he has utilized these laws is shown in this illustration, which is a cross-section of the hand instrument.



Inside of the wooden case *DD*, is placed the bar-magnet *NS*, having attached to one of its poles a piece of soft iron *E*, which becomes charged with magnetism of the same sign as the pole to which it is connected, and thus, really, forming part of the magnet. Around this piece of soft iron as a core, is wound the coil, consisting of about

60 ft. of No. 38 insulated copper wire, the ends being carried to the binding screws. A diaphragm, consisting of a circular plate of very thin iron, is placed at right angles to, and its centre opposite, the axis of the magnet, and as near it as possible not to touch when vibrating. This diaphragm is held firmly at its edge between the body of the case and the cap, by means of the wood screws, as shown.

By placing the instrument near the mouth while speaking, the diaphragm is made to vibrate by, and in accordance with, the sound-waves in the air, producing induced currents in the coil, which rapidly change in intensity and direction. When two telephones are properly connected by a line of wire, and to the ground, the electrical currents produced in the first instrument are conducted through the coil of the second one, and produce an increasing and diminishing attractive force in the magnet, and thus reproducing the vibrations of the first diaphragm, and consequently setting up the same sound-waves in the air near it. By placing the second instrument to the ear, the voice is heard in every intonation and quality, so that one is able to recognize the speaker by his voice.

This telephone, and two others in the body of the room, are connected, through about 4000 feet of wire, to similar instruments at No. 1111 Chestnut St. I will now signal to the person in attendance there, that we are ready, by means of this magneto-electric apparatus, and you will be able to hear the conversation carried on between that point and this room.[1]

The number of instruments in the circuit seems to make very little difference in their action; we had six or seven on the line yesterday, and apparently could hear as well as with only two. You will observe that the sounds conveyed can only be heard by placing the instrument to the ear, and therefore that the newspaper accounts of the speaking telephones being heard by a whole audience are mistakes.

The extreme distance through which this telephone can be used has not been definitely stated, but it has been used successfully between

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[1] This was done, and conversation was carried on with almost the same ease as if the person talking were personally present. Several instruments were placed in the circuit, in different parts of the room, and each one conveyed the sound equally well. After some experiments in speaking, the telephone on Chestnut Street was placed on the sounding-board of a piano while being played, and the tune was heard quite distinctly by those listening at the Institute.

points 32 miles apart. We made some experiments to-day with a rheostat, and spoke through a resistance equal to 550 miles of ordinary telegraph wire, stretched on poles. While theoretically the instrument is capable of being used on a wire of that length, practically it could not be so used, partly on account of the interference of induced currents from other wires, but principally because of what is termed escape or leakage, by which the current would be dissipated.

Great care is necessary in erecting lines for this telephone, for if the wire comes in close proximity to, or is carried on the same poles as, other lines, other currents are induced, producing confusion.

Part of the line we are now working on is carried on the poles of the city lines, and you can hear distinctly the click of the various Morse instruments operating them.

This telephone, the invention of Prof. A. Graham Bell, of Boston, should not be confounded with that of Elisha Gray, of Chicago, Ill., or of T. A. Edison, of Newark, N. J., both of which have been used in public for conveying musical sounds.

The two distinguishing features of the Bell telephone are that it is the only one not using a battery, and that conveys articulate speech by means of electrical currents.

The Bell telephone is now in practical use in New York and Boston, and several lines are in course of construction in this city.

Electric Light for Cities.—The municipal council of Exeter is the first public body in England which has officially recognized the value of the recent experiments in electric lighting. It has postponed a contemplated purchase of gas-works, under a hope that electricity will soon be shown to be more satisfactory as well as more economical. The three rival systems, of the Gramme machine, the Alliance machine, and the electric candles of Jablochkoff and Denayrouze, are continuing their experiments in Paris, on a large scale.—*Nature; Les Mondes.* C.

Compressibility of Liquids.—E. A. Amagat has conducted a series of investigations on the compressibility of volatile liquids, when the liquid state was maintained by pressure, at a temperature higher than their boiling point. The experiments were carried to a pressure as great as 39 atmospheres, the results being in the most satisfactory accordance with deductions from the mechanical theory of heat.—*Comptes Rendus.* C.

HISTORICAL SKETCH OF SHORTHAND IN PHILADELPHIA.[1]

The first shorthand writer in Philadelphia, of whom we have any knowledge, was Thomas Lloyd, who reported the debates in the first Congress of the United States, and was legal reporter in this city for many years. During this time, he returned to his native land (England), and published some of the debates, for which he was thrown into Newgate as a political prisoner, and remained there five years. He was the author of a system of shorthand, which he taught here. Reports of debates in the House of Representatives, taken by him in 1789, are extant; as also, reports of trials taken in 1820.

Later, M. T. C. Gould practiced and taught a system of shorthand, in this city.

In the year 1848, Oliver Dyer introduced Pitman's phonography, and taught a class in the Boys' High School. The influence of his teaching was soon felt, and the Philadelphia Phonographic Society was organized April 12th of that year. Among the members of that society, was Townsend Sharpless, who was an enthusiastic advocate of introducing phonography into the public schools, and of its use in business houses: an idea now practically realized in England; also, Franklin Peale, a noted mechanician of Philadelphia, and for many years Chief Coiner of the United States Mint; Clinton Gillingham; Oliver Dyer; and Robert Paterson, who was the author of the first book on Phonographic Reporting ever published in this country.

Many of the members of that society have been prominent advocates of phonography ever since, and are well known to phonographers throughout the United States. In addition to those above mentioned, are Professor Booth, the author of "Booth's Phonographic Instructor," and Prof. James A. Kirkpatrick, who taught the system for many years in the High School, and is now an officer of the Phonetic Shorthand Section of the Franklin Institute. The efforts of the members of that society appear to have been to perfect themselves in the art, and there is no record of any attempt to go further than that. The last meeting was held June 6, 1849.

The society had the honor of numbering in its list of members, Dennis Murphy, than whom there is no better phonographer, and

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[1] Translation of the phonography printed in audatype on page 225.

who is now, and for many years has been, the chief reporter in the United States Senate; and John McElhone, who has been permanently connected with the reportorial staff of the House of Representatives of the United States for nearly an equal length of time. These gentlemen commenced the study of phonography at the High School, under Mr. Dyer, which fact alone is a strong argument in favor of the utility of introducing phonography, as a regular study, into the public schools.

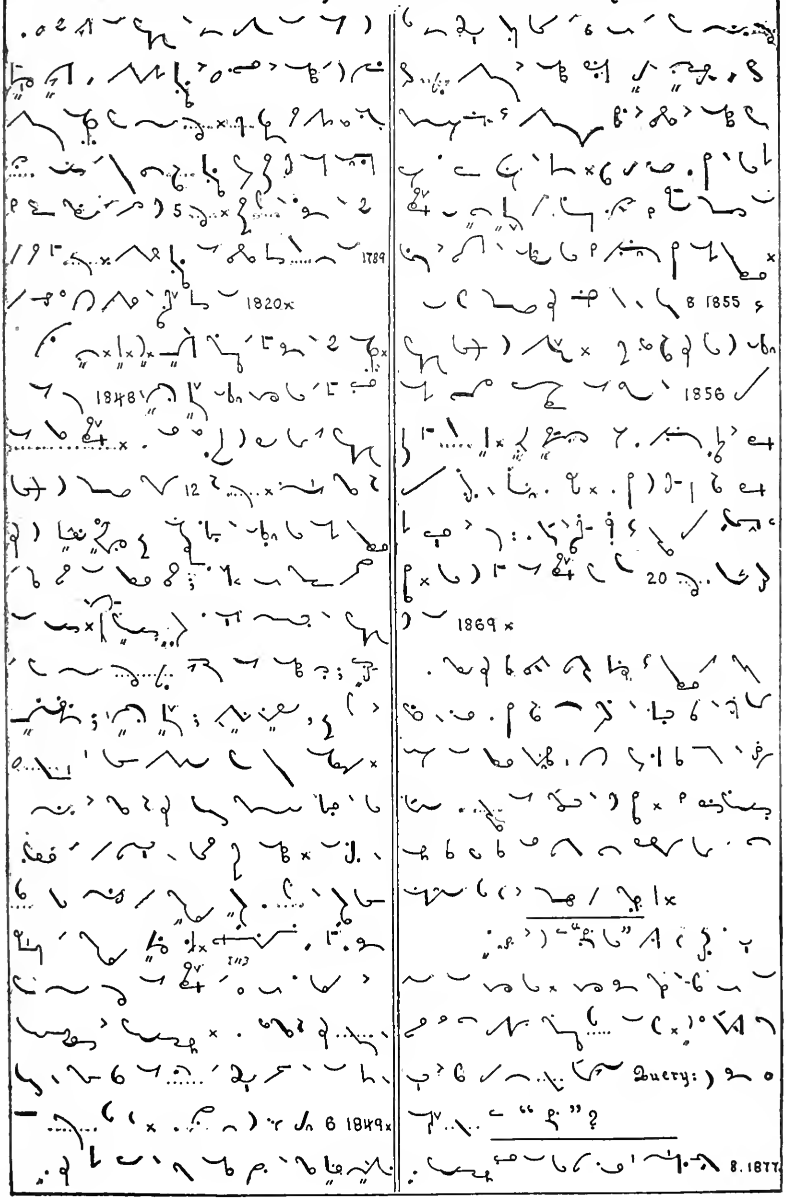
No other organized society existed up to February 8th, 1855, when the Philadelphia Phonographic Society was revived. Through the efforts of this society, phonography was introduced into the Girls' Normal School in the spring of 1856, where it was taught by D. Shepherd Holman, until the regular teachers of the school were competent to continue the instruction. The study was thrown out of this school at the close of the year, the Board of Controllers considering that the pupils were overcrowded with studies. Phonography was taught in the High School for over 20 years, being abandoned there in 1869.

The present society, it is hoped, will be able to demonstrate that the public schools are the proper places to commence the study of this important branch of education, which is of immediate value, not only in business pursuits, but also for the aid it is capable of constantly affording the pupils in the prosecution of their studies. As a Section of the Franklin Institute, it is believed its influence will be more sensibly felt and more enduring than that of the organizations which preceded it.

A student of the so-called "standard phonography," read without hesitation a note written in Pitman's phonography. Pitman's system preceded all others now in use, and is more widely practiced than any other. As it has borrowed from none of the others, we may put the following query: Whose system is entitled to be called "standard?"

The Franklin Institute class in phonography will commence on Monday, October 8th, 1877.

Historical Sketch of Shorthand in Philadelphia.



A New Unit of Light for Photometry.—In a paper read before the Physical and Chemical Sections of the British Association at Plymouth,[1] A. Vernon Harcourt, F. R. S., etc., proposes as a substitute for the standard candle for photometric measurements, the use of a hydrocarbon vapor mixed with air, and burnt through a large burner. The hydrocarbon used, is that portion of American petroleum, which, after repeated rectifications, distils at a temperature not exceeding 50° C., and consists almost entirely of pentine, the fifth member of the series of paraffines.

To prepare the gas, he draws into a gasholder the required volume of air, chosen according to the capacity of the holder, and corrected for temperature, pressure and tension of aqueous vapor; then the corresponding portion of pentine is poured into the gasholder from a measuring flask, connected by means of glass and caoutchouc tubing to a tap in the upper plate.

He proposes to maintain a proportion of 600 volumes of air to one of liquid pentine. A few minutes are sufficient for the volatilization of the liquid, and a few hours for perfect diffusion. The unit which he proposes, and which he claims is adjusted to correspond to the light of a sperm candle consuming 120 grains of sperm per hour, is the light given by a mixture of 7 volumes of pentine gas with 20 volumes of air, burning from a $\frac{1}{4}$-inch orifice at the rate of a cubic foot per hour, under the standard condition of 60° F. and 30 inches pressure. K.

Old Lightning Rods.—Dr. Munke quotes a passage from the Talmud, written in the fourth or fifth century of our era, permitting the use of iron "as a protection from lightning and thunder." Wiedermann, in an editorial note, adds that the Egyptians appear to have used gilded masts "for warding off the bad weather coming from heaven."—*Ann. der Phys. u. Chem.* C.

Experimental Composition of Light.—Wm. Terrill arranges seven lanterns, with glass slides stained to imitate the different colors of the spectrum. By turning the lanterns so that the projected circles overlap, a circle of white light is produced. Interesting experiments with complementary colors may be performed in the same way.—*Nature.* C.

[1] See *Chemical News*, Sept 7th, 1877.

Electrolytic Experiments.—M. Gramme reports three sets of experiments with his machine on the electrolysis of sulphate of copper. The results show that intensity is much more important than quantity, and that little or no work is expended in the electrolysis of sulphate of copper with copper anodes.—*Comptes Rendus.* C.

Alteneck Induction-Machines.—Prof. Weinhold adds his testimony to that of the Russian experimenters, in favor of the von Hefner-Alteneck inductors, made by Siemens and Halske, in Berlin. He represents them as having the best form for powerful currents, giving most compactly, at the least cost and with the least expenditure of power, the strongest possible currents.—*Bayer. Ind.- u. Gew.-Blatt.* C.

Geodetic Observations by Night.—F. Perrier has made a comparative study of day and night observations, from which he concludes "that azimuthal observations by night possess a degree of precision at least equal, if not superior, to that of observations by day." He will make a special study of the effects produced upon the azimuthal measures by the torsion of the wooden signals under the direct action of the sun's rays.—*Comptes Rendus.* C.

Pulsation and Vibration.—C. A. Bjerknes finds that "simultaneous and synchronous vibrations manifest mean forces of the second, third and fourth degrees; and for these new apparent forces the principle of equality between action and reaction subsists, while they also show a great resemblance to the forces of nature. Thus two spheres, having concordant pulsations, attract each other inversely as the square of the distance; they repel each other according to the same law if their pulsations are opposed."—*Comptes Rendus.* C.

Hardening of Oak.—Among the numerous instances of the hardening of oak under water, Berthier mentions remains of bridge piles, at Rouen, which were driven in 1150. They resembled ebony in texture and color, and the change was attributed to peroxide of iron. M. Charil-Marsaines, in destroying the remains of a dike which was built by Vaubam in 1681, found that the oak timbers had the same appearance. He did not examine them chemically, but he quotes experiments of Buffon, to account for the probable presence of an iron oxide.—*Ann. des Ponts et Ch.* C.

Plastic Flow.—Prof. Friedr. Kick and Asst. Ferd. Polak, of Prague, have experimented upon the internal displacements in soft masses or plastic bodies, under external pressures. Their experiments cover only a small portion of Tresca's field, but they are neatly treated, and formulæ of deformation simply deduced. They conclude that the laws of deformation are the same for all bodies which admit of internal displacements through pressure. Some of their experiments with clay may have important bearings on geological erosion.—*Dingler's Polyt. Jour.* C.

Barometric and Magnetic Rotations.—In discussing the observations of Stonyhurst College, attention was called to a probable connection between the movements of the barometer and those of the magnetic declination (see *Les Mondes*, July 7, 1877). Communications were presented to the American Philosophical Society in 1863 (Proc. A. P. S., ix, 283, 291, etc.), demonstrating such a connection, and the Society awarded its Magellanic premium of a gold medal for the discovery, in 1864.—*Ibid.*, p. 486. C.

A New Method of Organic Synthesis.—C. Friedel and J. M. Crafts have effected many syntheses of complex hydrocarburets and acetones, by means of reactions initiated by metallic chlorides, iodides and bromides. The action of the chlorides is generally the neatest; the organic chlorides are attacked by the metallic chloride, with loss of chlorhydric acid, formed from two molecules, of which one furnishes the chlorine, and the other the hydrogen, and of which the two residues combine. They hope, by these reactions, to obtain new radicals of the fatty and aromatic series.—*Comptes Rendus.* C.

Coupled-Leveling Instrument.—Engineer Aita, being charged with the survey of Padua for drainage and water-service, devised a coupled level which remedies many of the surveying difficulties of tortuous and narrow streets. It consists of two glass tubes, doubly clamped to graduated staffs, and connected by a caoutchouc tube of any desired length. The two clamps are movable, the glass tubes being partly, and the connecting tube wholly, filled with water. The observer at each end brings one of the clamps to the water level, and enters the scale-reading in his note-book. When the books are compared, the difference of readings gives the difference of altitudes.—*Il Politecnico.* C.

British Encouragement to Science.—An influential deputation of members of Parliament lately waited on the Chancellor of the Exchequer, to advocate the claims of the Scottish Meteorological Society. Sir Stafford Northcote said that the Treasury was prepared to grant £1000 for services rendered to the Government during the past twenty years; and he gave encouragement for future appropriations.—*Nature.* C.

Measurement of Water Suspended in Steam.—P. Gazzi, in view of the difficulties introduced into calculations of boiler efficiency by foaming or other mechanical suspension of vapor, has described an apparatus for determining the degree of humidity, as well as for finding the density, either of saturated or of dry steam, at high pressures. His invention was suggested, in part, by the recent investigations of Hirn, Leloutre, and Hallauer.—*Il Politecnico.* C.

Influence of Mechanical Action on Crystallization.—Supersaturated solutions of many salts, often spontaneously deposit crystals which are less hydrated than the common salt. In many cases, before the point of spontaneous deposit is reached, a crystal of the less hydrated form will start the deposit. In such cases a brisk friction against the walls of the vessel will often produce crystallization. D. Gernez has observed three modes of this mechanical action: 1, the simple production of the least hydrated crystals; 2, the production of the most hydrated crystals, in solutions where the other hydrate would form in contact with a crystal; 3, the production of either salt, under different degrees of friction.—*C. R.* C.

Cooling Goblet.—M. Toselli has invented a simple contrivance for the rapid cooling of liquids. It consists of a cylindrical cup, for holding any beverage, into which may be plunged an inner goblet, shaped like an inverted truncated cone, and having a lid which rests on the outer cup. Putting 150 grammes of nitrate of ammonia in the inner goblet, filling it with cold water, and stirring it so as to hasten the solution, the temperature of the outer liquid is soon reduced at least 12° C. (22° F.). The salt may be used for an indefinite period, by spreading it on a plate after each trial, and exposing it to the sun until it crystallizes anew. The inventor prepares a salt which will lower the temperature 28° C. (50° F.) in the warmest countries.—*Les Mondes.* C.

Hydraulic Engineering in France.—M. de Lesseps has called the attention of the French Academy to the distribution of the waters flowing from the natural declivities of the French territory, and to the improvement of internal navigation. In view of the wealth of its hydrographic basins, of their importance, and of the facility of inter-communication, France is the most favored country of Europe. Far from profiting by this happy position, and notwithstanding the abundance of rivers, the meadows are of a limited extent, large tracts are exposed to droughts which oppose the improvement of their culture, and immense amounts of valuable material are continually wasted. M. Herve Mangon estimates that the volume of mud annually carried off by the Durance, bears to the sea more than 14,000 tons of nitrogen, in the state of combination which is best fitted for the nourishment of cultivated plants. At the same time, agriculturists buy from foreign countries, at great sacrifice, other nitrogenous matters, and the importation of guano, which scarcely furnishes so large a quantity of nitrogen to French agriculture, costs it thirty million francs per annum. The same mud contains nearly 100,000 tons of carbon, or as much as would be furnished by a forest of 50,000 hectares.

M. Cotard proposes to store all the summit-waters, in the basin of the Garonne and the Adour, and distribute them in such manner as to feed the channels of internal navigation, facilitate the transport of industrial products to good markets, and avoid the accumulation of stagnant waters in unhealthy marshes. The French Agricultural Society endorses his project with strong recommendations.

Hubert Delisle sets forth all the benefits of the water-courses in transporting bulky and cheap products, regarding it as an important object to put all parts of the territory into easy communication. He would develop five great lines: 1, the Eastern line, putting Havre and the northern ports in communication with Alsace and Switzerland by the Seine, the enlargement of the sluices of the canal from the Marne to the Rhine, and needful improvements along that canal. 2, the line of the grand-girdle canal, connecting the rich basins of the Oise, the Aisne, the Marne, the Aude, the upper Seine, and the Yonne, thus establishing relations, on one hand with the navigable waters of the north, on the other with the channels of Burgundy and Orleans. 3, the Western line, to put Nantes and the departments watered by the Loire, the Santhe, the Mayenne, the Cher and the Vienne, in communication with Paris, the north, the east and the

centre of France. 4, the southwestern line, joining the basins of the Dordogne and the Garonne to the capital by an artery which would tap the coal basins, including the canal of the great *Landes*, uniting Bayonne and Bordeaux. 5, the line of the Saône and the Rhone, by its natural and artificial affluents, penetrating far into the interior and surrounding the Alps, is capable of serving central France, Switzerland, Belgium, and Western Germany; it has, therefore, in view of the commercial relations of the continent with the Mediterranean, an importance unrivaled by any other river in Europe.

Capt. Sibour shows that the improvement of the navigable ways and the appropriation of the canal and harbor of Bouc, should be completed by opening a canal of 7 kilometres between the pool of Berre and the harbor of Marseilles, permitting an immense development of commerce and industry as well as an indispensable security for vessels. Twelve years ago, Baron Chabaud Latour, Engineering Inspector-General, wrote: "The government should not hesitate to employ the magnificent natural harbor of the port of Berre, and to execute the civil and military works which will make it one of the most powerful centres of commercial activity in the world."

"Water courses," says M. Krantz, "awaken agricultural improvements, encourage the establishment of workshops, facilitate the development of mines, quarries and forests, increase the public wealth, and the State receives its share of the wealth which they create." M. de Lesseps hopes that the scientific concurrence and the united influence of the members of the Academy, will contribute to the realization of their several plans.—*Comptes Rendus.* C.

Iron Railway Ties.—Engineer G. Cattaneo describes the advantages of the Hilf system, its gradual extension and success in Germany, the proposed modifications of Hensinger, and the reasons for its adoption in Italy.—*Il Politecnico.*

Holmes' Distress Signal.—The signal is made by a projectile thrown from a mortar to distances varying from 500 to 2500 metres. On touching the water, it floats on the surface, and immediately blazes, emitting a very white and intense flame for thirty or forty minutes. A half-dozen of these projectiles, shot from a besieged building, would surround it with a line of inextinguishable light, so that the occupants, while in the shade themselves, could examine the torpedoes and other offensive contrivances of the enemy.—*L. M.* C.

Book Notice.

A Treatise on the Use of Belting for the Transmission of Power. Largely illustrated. By John A. Cooper. 8vo, pp. 300. Philadelphia, 1877. Claxton, Remsen & Haffelfinger.

Of all the appliances used by the mechanical engineer, there is none upon which writers disagree so widely as the transmission of power by belting, and therefore a collection of data from actual practice became very desirable. Such a collection was begun some years ago by Mr. Cooper, and published in The Journal of the Franklin Institute as obtained.

Later, Mr. Cooper saw the great advantage of having in one volume all the important literature on the subject, which, up to that time, was so scattered as not to be available, except with great labor to the few having access to the best engineering libraries.

This work has been performed very exhaustively by the author, resulting in the most complete collection of rules, tables and statistics upon the use of belts now in print.

He has given his own rules and formulæ for calculating the width, strength and arrangement of belts for all kinds of service, but being simply a seeker after truth, has not hesitated to place beside them the rules and opinions of others, even when they do not agree with his own, and in every case he has given full credit to those whose opinions he has borrowed.

To make an exhaustive review of this valuable work would be to write a second treatise, but it may be stated that among other valuable matter, the essay of Mr. Robert Briggs, the experiments of Mr. John H. Town, and a full translation of the entire treatise of M. Morin on this subject, are given. There is also much valuable information regarding transmission by endless ropes and by rolling contact.

Exception may be taken to the repetition consequent upon quoting so many original papers in full, but this was unavoidable in carrying out the author's plan of making it a standard work of reference, and as such it makes it all the more valuable.

After all the labor of preparing such a work, Mr. Cooper has not buried it between the covers without a proper guide to its contents, as is sometimes the case with authors, but has given a thorough and complete index, covering ten pages. K.

THE METHOD OF LEAST SQUARES APPLIED TO A HYDRAULIC PROBLEM.

By MANSFIELD MERRIMAN, Ph. D., Instructor in the Sheffield Scientific School, New Haven, Conn.

In the great hydraulic survey of the Mississippi river, conducted by Humphreys and Abbot, numerous velocity observations with double floats, were taken at different depths below the water surface. The combined results of all these observations are given on page 244 of the second edition of their *Report on the Physics and Hydraulics of the Mississippi River*, and are as follows:

Depth of float below surface.	Observed velocity in feet per second.	Remarks.
Surface.	3·1950	"Grand mean of all observations taken from anchored boats, combined in ratio of number of observations at each determined point. They were taken at Carrolton and Baton Rouge, in 1851. Each point is fixed by 222 observations. Mean maximum velocity, which is 0·297 *D* below the surface, is 3·2611 ft. Mean wind is down force 0·2. Mean velocity of river is 3·3814 ft. per second."
0·1 *D*	3·2299	
0·2 *D*	3·2532	
0·3 *D*	3·2611	
0·4 *D*	3·2516	
0·5 *D*	3·2282	
0·6 *D*	3·1807	
0·7 *D*	3·1266	
0·8 *D*	3·0594	
0·9 *D*	2·9759	
Bottom.		

These observations may be graphically represented by dividing a vertical line equal to *D*, the depth of the river, into ten equal parts, through the points of division drawing horizontal lines, and laying off upon these the observed velocities. The points thus obtained will show more clearly than the above figures, the manner in which the velocity varies from the surface to the bottom. In the diagram below the points enclosed within small circles represent these observations. Each horizontal division of the diagram is 0·1 ft. per second, and each vertical division represents one-tenth of *D*.

Now if we can obtain the equation of a curve passing through these points, we shall have not only a formula from which the velocities at all intermediate points may be computed, but also an expression of the law governing the velocities at different depths.

Humphreys and Abbot give reasons for concluding that a parabola, whose axis is horizontal, will better accord with these points than any other curve of the second degree. Their method of deducing the

equation of this parabola was one of trial—the constants of the equation were first virtually assumed, then corrected by comparison with the observations, after which the curve was plotted on tracing paper, and being laid upon the points "the eye at once detects if a close approximation can be made by slightly changing the depth of the axis," or the value of the parameter. This process is fully described on page 243 of the Report (second edition), and by it "the following equation was deduced for the parabola corresponding to the grand mean curve of observations:

$$V = -\ 0·79222\, d_{11}^{\,2} + 3·2611,$$

in which V is the velocity in feet, and d_{11} is the distance from the axis, in fractional parts of the whole depth, considered unity." The position of the axis is stated as 0·297 D below the surface. The last three columns of the following table, which are taken from page 244 of the Report, "exhibit the comparison between the observations and this parabola."

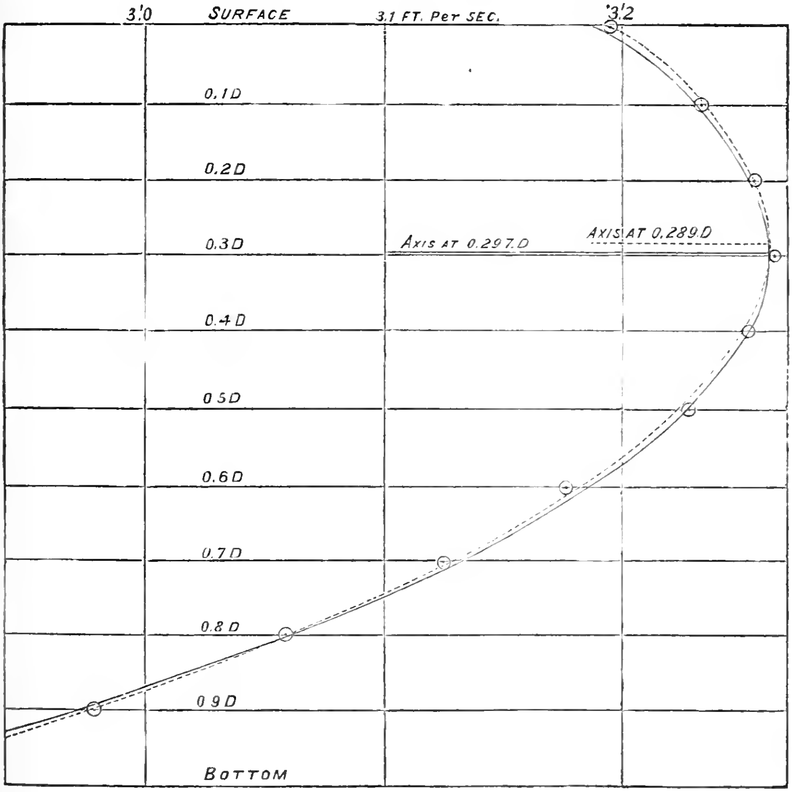
TABLE I.

Depth of float below surface.	Corresponding value of d_{11}.	"Velocity by observation."	"Veloc. by above equation."	"Difference."
		FEET.	FEET.	FEET.
Surface.	+ 0·297	3·1950	3·1901	+ 0·0049
0·1 D	+ 0·197	3·2299	3·2293	+ 0·0006
0·2 D	+ 0·097	3·2532	3·2525	+ 0·0007
0·3 D	— 0·003	3·2611	3·2600	+ 0·0011
0·4 D	— 0·103	3·2516	3·2525	— 0·0009
0·5 D	— 0·203	3·2282	3·2274	+ 0·0008
0·6 D	— 0·303	3·1807	3·1873	— 0·0066
0·7 D	— 0·403	3·1266	3·1313	— 0·0047
0·8 D	— 0·503	3·0594	3·0596	— 0·0002
0·9 D......	.....— 0·603....	.......2·9759......	.......2·9719.......	.....+ 0·0040
Bottom.	— 0·703		2·8685	

On the accompanying diagram I have laid off the values in the column headed "Velocity by above equation," and drawn through the points the full line curve. The agreement between this curve and the observations is very close.

The method used for deducing this equation is long and tedious, as anyone may satisfy himself by trial, and moreover very unscientific, since there is no reason to suppose that it gives the curve best agreeing with the observations, and since no two persons following it would arrive at the same result. The Method of Least Squares, however,

furnishes a simple and strictly scientific process by which the exact equation of the curve most closely agreeing with the observations can be determined. In the last number of this JOURNAL I gave a discussion of the mathematical principles at the basis of this Method, and as an example of its use in practice, will now apply it to the deduction of the parabola best agreeing with the above observations.



The general equation of a parabola whose axis is horizontal, is

$$V = Ad^2 + Bd + C.$$

The depth of the river is here taken as unity, and d is any fractional part of that depth measured from the water surface downward; V is the velocity at a point whose depth is d; A, B and C are constants, to be determined from the observations, fixing the dimensions and position of the curve.

The first of the above observations shows for the surface, or $d = 0$, a velocity of 3·1950 feet per second. These values inserted in the above parabolic expression, give

$$3{\cdot}1950 = C$$

as a first *observation equation*. The second has for $d = 0{\cdot}1$, $V = 3{\cdot}2299$, and these inserted, give

$$3{\cdot}2299 = 0{\cdot}01\,A + 0{\cdot}1\,B + C$$

as a second observation equation. The third has for $d = 0{\cdot}2$, $V = 3{\cdot}2532$, from which

$$3{\cdot}2532 = 0{\cdot}04\,A + 0{\cdot}2\,B + C$$

results as a third observation equation. In like manner each observation furnishes us with an observation equation, and thus we have in all the ten following equations, in which the coefficients of B are the successive values of d, those of A the values of d^2, and the first members the observed velocities:

$$\begin{aligned}
3{\cdot}1950 &= & & & + C \\
3{\cdot}2299 &= 0{\cdot}01\,A &+ 0{\cdot}1\,B &+ C \\
3{\cdot}2532 &= 0{\cdot}04\,A &+ 0{\cdot}2\,B &+ C \\
3{\cdot}2611 &= 0{\cdot}09\,A &+ 0{\cdot}3\,B &+ C \\
3{\cdot}2516 &= 0{\cdot}16\,A &+ 0{\cdot}4\,B &+ C \\
3{\cdot}2282 &= 0{\cdot}25\,A &+ 0{\cdot}5\,B &+ C \\
3{\cdot}1807 &= 0{\cdot}36\,A &+ 0{\cdot}6\,B &+ C \\
3{\cdot}1266 &= 0{\cdot}49\,A &+ 0{\cdot}7\,B &+ C \\
3{\cdot}0594 &= 0{\cdot}64\,A &+ 0{\cdot}8\,B &+ C \\
2{\cdot}9759 &= 0{\cdot}81\,A &+ 0{\cdot}9\,B &+ C.
\end{aligned}$$

From these equations we have now to find the values of A, B and C, and substitute them in the above general parabolic formula. But as there are ten equations, and only three unknown quantities, no values can be found which will exactly satisfy them all. The best that we can do is to find the *most probable* values of A, B and C, and these, according to the principle of Least Squares, are the values which make the sum of the squares of the residual errors (or the differences between the observed and computed velocities) a minimum.

The following is the rule which the Method of Least Squares furnishes for finding the values of A, B and C, which satisfy this condition:—

Deduce a *normal equation* for A, by multiplying each observation equation by the coefficient of A in that equation, and adding the results; deduce also a normal equation for B, by multiplying each

observation equation by the coefficient of B in that equation, and adding the results; also one for C, by multiplying each equation by the coefficient of C, and adding. Thus we shall have three normal equations, each containing three unknown quantities, and the solution of these equations will give us the most probable values of A, B and C.[1]

The coefficient of A in the first of the above observation equations is 0, in the second it is 0·01, in the third it is 0·04, etc. Multiplying then the first observation equation by 0, the second by 0·01, the third by 0·04, etc., we have

$$\begin{aligned}
0{\cdot}032299 &= 0{\cdot}0001\,A + 0{\cdot}001\,B + 0{\cdot}01\,C\\
0{\cdot}130128 &= 0{\cdot}0016\,A + 0{\cdot}008\,B + 0{\cdot}04\,C\\
0{\cdot}293499 &= 0{\cdot}0081\,A + 0{\cdot}027\,B + 0{\cdot}09\,C\\
0{\cdot}520256 &= 0{\cdot}0256\,A + 0{\cdot}064\,B + 0{\cdot}16\,C\\
0{\cdot}807050 &= 0{\cdot}0625\,A + 0{\cdot}125\,B + 0{\cdot}25\,C\\
1{\cdot}145052 &= 0{\cdot}1296\,A + 0{\cdot}216\,B + 0{\cdot}36\,C\\
1{\cdot}532034 &= 0{\cdot}2401\,A + 0{\cdot}343\,B + 0{\cdot}49\,C\\
1{\cdot}958016 &= 0{\cdot}4096\,A + 0{\cdot}512\,B + 0{\cdot}64\,C\\
2{\cdot}410479 &= 0{\cdot}6561\,A + 0{\cdot}729\,B + 0{\cdot}81\,C,
\end{aligned}$$

and the sum of these, or

$$8{\cdot}828813 = 1{\cdot}5333\,A + 2{\cdot}025\,B + 2{\cdot}85\,C,$$

is the normal equation for A.

The coefficients of B in the first observation equation is 0, in the second 0·1, in the third 0·2, etc. Multiplying then the first, second, third, etc., equations by 0, 0·1, 0·2, etc., respectively, we have

$$\begin{aligned}
0{\cdot}32299 &= 0{\cdot}001\,A + 0{\cdot}01\,B + 0{\cdot}1\,C\\
0{\cdot}65064 &= 0{\cdot}008\,A + 0{\cdot}04\,B + 0{\cdot}2\,C\\
0{\cdot}97833 &= 0{\cdot}027\,A + 0{\cdot}09\,B + 0{\cdot}3\,C\\
1{\cdot}30064 &= 0{\cdot}064\,A + 0{\cdot}16\,B + 0{\cdot}4\,C\\
1{\cdot}61410 &= 0{\cdot}125\,A + 0{\cdot}25\,B + 0{\cdot}5\,C\\
1{\cdot}90842 &= 0{\cdot}216\,A + 0{\cdot}36\,B + 0{\cdot}6\,C\\
2{\cdot}18862 &= 0{\cdot}343\,A + 0{\cdot}49\,B + 0{\cdot}7\,C\\
2{\cdot}44752 &= 0{\cdot}512\,A + 0{\cdot}64\,B + 0{\cdot}8\,C\\
2{\cdot}67831 &= 0{\cdot}729\,A + 0{\cdot}81\,B + 0{\cdot}9\,C,
\end{aligned}$$

and these added together, give

$$14{\cdot}08957 = 2{\cdot}025\,A + 2{\cdot}85\,B + 4{\cdot}5\,C,$$

as the normal equation for B.

[1] The proof of this rule may be found in all books on the subject. See, for instance, *Elements of the Method of Least Squares* (London and New York, Macmillan & Co., 1877), page 43.

The coefficient of C is unity in each of the observation equations. Multiplying by unity leaves them unchanged, and hence their sum, or

$$31\cdot7616 = 2\cdot85\,A + 4\cdot5\,B + 10\,C,$$

is the normal equation for C.

The ten observation equations have thus been reduced to the three normal equations:

$$\begin{aligned} 8\cdot828813 &= 1\cdot5333\,A + 2\cdot025\,B + 2\cdot85\,C \\ 14\cdot089570 &= 2\cdot0250\,A + 2\cdot850\,B + 4\cdot50\,C \\ 31\cdot761600 &= 2\cdot8500\,A + 4\cdot500\,B + 10\cdot00\,C, \end{aligned}$$

and solving these by any algebraic method, we obtain

$$A = -\,0\cdot7653, \quad B = +\,0\cdot44253, \quad C = +\,3\cdot19513,$$

and these are the most probable and best values. Inserting them in the general parabolic equation for the velocity,

$$V = Ad^2 + Bd + C,$$

we have

$$V = -\,0\cdot7653\,d^2 + 0\cdot44253\,d + 3\cdot19513,$$

and this is the equation of the parabola with horizontal axis, which agrees best with the above observations. The following table shows a comparison of observed velocities with those computed from this formula:

TABLE II.

Depth of float below surface.	Corresponding value of d.	Observed velocity.	Computed velocity.	Difference.
		FEET.	FEET.	FEET.
Surface.	0·0	3·1950	3·1951	—0·0001
0·1 D	0·1	3·2299	3·2317	—0·0018
0·2 D	0·2	3·2532	3·2530	+0·0002
0·3 D	0·3	3·2611	3·2590	+0·0021
0·4 D	0·4	3·2516	3·2497	+0·0019
0·5 D	0·5	3·2282	3·2251	+0·0031
0·6 D	0·6	3·1807	3·1851	—0·0044
0·7 D	0·7	3·1266	3·1299	—0·0033
0·8 D	0·8	3·0594	3·0594	0·0000
0·9 D......	........0·9........	.......2·9759.......	.......2·9735.......	..... +0·0024
Bottom.	1·0		2·8724	

The dotted curve in the above diagram has been plotted from these computed velocities, and it will be noticed that it corresponds much closer to the observed points than that deduced by Humphreys and Abbot. The precision of the two curves may be compared by means of the sums of the squares of the differences between the observed

and computed velocities. Squaring each of the differences in Table I, and taking the sum of these squares, we have 0·00010921; doing the same with the differences in Table II, we have 0·00005693, or only about one-half as much. Hence, according to a principle of the Method of Least Squares, the precision of the dotted curve is to that of the full line curve nearly as 1·4 is to 1. A comparison of the differences in Tables I and II is also interesting—of their signs as well as their values.

In Humphreys and Abbot's parabolic equation,

$$V = -\,0{\cdot}79222\,d_{11}^2 + 3{\cdot}2611,$$

the origin of co-ordinates is on the axis of the curve at a distance 3·2611 to the left of the vertex, and d_{11} is the distance from that axis in decimal parts of the depth, considered as unity. Hence the equation cannot be used for computing velocities, unless the depth of the axis below the water surface is known. This is stated at 0·297 D (see Remark quoted at beginning of this article). Thus, to find the velocity at a depth of 0·1 D, we must substitute in the equation $d_{11} = 0{\cdot}197$. But in the equation here deduced,

$$V = -\,0{\cdot}7653\,d^2 + 0{\cdot}44253\,d + 3{\cdot}19513,$$

the origin is on the water surface, and d is the depth below that surface in decimal parts of the whole depth, taken as unity. Velocities may hence be directly computed by substituting for d successive depths below the surface. The position of the axis is, however, readily obtained by dividing the coefficient of d by twice the coefficient of d^2, or

$$d_{11} = \frac{0{\cdot}44253}{1{\cdot}5306} = 0{\cdot}289,$$

and substituting this for d in the equation, we have $V = 3{\cdot}2591$, as the computed maximum velocity. The equation may hence also be written

$$V = -\,0{\cdot}7653\,d_{11}^2 + 3{\cdot}2591,$$

it being remembered that the axis is 0·289 D below the surface.

The time needed for an ordinary computer to apply the Method of Least Squares to the above problem, is about three or four hours. The process is rapid, it is founded on universally accepted mathematical principles, it has long been recognized and applied in Astronomy, Geodesy and Physics for the determination of such empirical

formulæ, and it gives no chance for any individual choice in drawing the curve.

The parabolic law for velocities at different depths, is the foundation of Humphreys and Abbot's "experimental theory" of the flow of water in rivers, and it is reasonable to suppose that in establishing that law, especial care would have been taken to insure accuracy of calculation, and of statement. That a tedious approximative process should have been chosen for determining the parabola, instead of the strictly scientific Method of Least Squares, is a matter of surprise and regret.

A few errors, which I have discovered in the Mississippi Report, while making the above investigation, may properly be stated here, as they relate to the parabola of vertical velocities. I will explain them by means of the following table:—

Depth of float below surface.	Corresponding value of d_{11}.	Differences between Observed and Computed Velocity.		
		I.	III.	IV.
		FEET.	FEET.	FEET.
Surface.	0·297	+ 0·0049	+ 0·0038	+ 0·0049
0·1 *D*	0·197	+ 0·0006	— 0·0005	+ 0·0006
0·2 *D*	0·097	+ 0·0007	— 0·0004	+ 0·0007
0·3 *D*	0·003	+ 0·0011	0·0000	+ 0·0011
0·4 *D*	0·103	— 0·0009	— 0·0011	0·0000
0·5 *D*	0·203	+ 0·0008	— 0·0003	+ 0·0008
0·6 *D*	0·303	— 0·0066	— 0·0077	— 0·0066
0·7 *D*	0·403	— 0·0047	— 0·0058	— 0·0047
0·8 *D*	0·503	— 0·0002	— 0·0013	— 0·0002
0·9 *D*	0·603	+ 0·0040	+ 0·0029	+ 0·0040

Column I gives the differences from Table I above; these are stated in the Report to have been computed by subtracting from the observed velocities, the velocities given by the equation,

$$V = -0·79222\, d_{11}^{\,2} + 3·2611,$$

the axis being at a depth 0·297 *D* below the water surface. Inserting in this formula the values of d_{11}, and computing the differences, I was surprised to find that they all disagreed with those in column I. For example, the value of d_{11} for the point 0·1 *D* is 0·197, then $V = -0·79222\,(0·197)^2 + 3·2611 = 3·2304$; the observed velocity is 3·2299, hence the difference is $-0·0005$. Column III contains

the differences as computed by me from the above equation, and it will be noticed that, with one exception, they are less than those in column I, by the constant quantity 0·0011. Taking then the parabolic equation, whose constant term is 3·2600,

$$V = -0{\cdot}79222\, d_{11}^2 + 3{\cdot}2600,$$

and finding the differences, I obtain column IV, and these all agree with those in I, except that for 0·4 *D* there results 0·0000, instead of — 0·0009.

It hence appears that either the computed velocities and differences, quoted above in Table I from the Mississippi Report, are erroneous, or that the number 3·2611 in the parabolic formula should be 3·2600. Even under this latter supposition there is an error in finding the value for 0·4 *D*. Such blunders—whether due to the carelessness of computer, copyist, or printer—ought not to have occurred in the second edition of a book like this, and least of all at the very foundation of an important theory.

Palæologic Comparative Anatomy.—The lime in egg-shells is not amorphous, but more or less crystalline, presenting many analogies to the shells of mollusks. M. Matheron found in the cutaneous beds near Rognac, two large segments of a sphere in ellipsoid, which he thought to be the fragments of an egg larger than that of the *Aepyorris*, but he hesitated whether to attribute them to a gigantic bird, or to a reptile. M. P. Gervain examined their structure microscopically, comparing them with egg shells of various birds, turtles, crocodiles, and geckoes. The differences of structure are described with interesting detail in his paper, leading him to the conclusion that the eggs resemble those of the Chelonians rather than Crocodilians, while their volume tends to attribute them to the *Hypselosaurus*, which has been thought to be more like the Crocodilians than like the Chelonians. He therefore refers them to a reptile of undetermined classification, analogous to certain *Emyde-saurians.* If that reptile was the *Hypselosaurus*, as there are many reasons for believing, it must have resembled the Chelonians more than the known fragments of its skeleton would lead us to suppose. —*Comptes Rendus.* C.

ON A NEW PROCESS FOR THE ELECTRICAL DEPOSITION OF METALS, AND FOR CONSTRUCTING METAL-COVERED GLASS SPECULA.[1]

By Professor ARTHUR W. WRIGHT, Yale College.

In a paper by the writer, published in this Journal, January, 1877, an account was given of a method of producing metallic films upon the inner surface of exhausted glass tubes, by the action of a succession of energetic electrical discharges. The thickness of these films could be varied, from a tenuity such that the coating barely gave indications of a metallic lustre, and scarcely dimmed the intensity of transmitted light, to the point where perfect opacity was attained, by simply continuing the action of the current for a shorter or longer time. They were produced by forming the negative electrode of the metal to be deposited, exhausting the tube, and passing through it the current from an induction coil. The metallic coatings thus obtained, as seen from the exterior, were very brilliant, but the condition of the inner surface was not readily observed, and the nature of the process made it seem probable that they possessed a dull or even a frosted surface. With a view to obtain the films in a form better suited for examination, a modification of the apparatus was contrived, by which they could be deposited upon pieces of plane glass. At first this object was attained by inserting narrow slips of glass into the tube by the side of the electrode, in the manner suggested in my former paper, and very good results were gained. But, as the nearer portion of the plate received a larger share of the metal, the thickness of the deposit was not uniform, and it was found necessary to construct a special apparatus, in which the relative positions of the plate and the electrode could be varied, so as to give the latter an equal action upon all parts of the surface to be covered. The plan employed was as described in the following paragraphs.

A rather thick-walled glass globe, about seven centimetres in diameter, blown upon the end of a tube twenty-five centimetres long and fifteen millimetres in diameter, was used to form the receiver. The top of the globe opposite the tube was cut off, so as to form an opening forty millimetres in diameter, and the edge ground flat, in a plane perpendicular to the axis of the tube. The end of the latter

[1] From the *American Journal of Science and Arts*, September, 1877.

was drawn somewhat smaller in a gas-flame, and a glass stop-cock attached to it with cement. A little way above this, a platinum wire was fused into the glass to serve as the positive electrode. The cover of the vessel was made by cutting from a similar globe a portion corresponding in size to the part removed, but with the neck attached, the two pieces being carefully ground so as to fit closely. When they were placed together, a little cement applied to the outside along the line of juncture rendered the joint perfectly air-tight. The tube or neck of the cover was five centimetres long, and was also somewhat reduced at the extremity by drawing it smaller. Into this was cemented a small and thick-walled tube extending to a point near the centre of the globe. A platinum wire was placed in this tube, and was fused in at the top, enough being left projecting to form a small loop for the attachment of the wire from the coil. The inner end of the wire terminated at about one centimetre from the lower end of the glass tube. Into the latter was slipped a wire of the metal to be deposited, which, in all cases, was the negative electrode,—the part within the tube being long enough to make good contact with the platinum wire, and being bent somewhat so as to cause it to retain its place by friction. In some of the experiments a different cover was used, made from a glass funnel, the neck of which was left somewhat longer to afford more room for the swinging electrode, as described below, and the tube carrying the latter was fitted into the top by grinding so as to make an air-tight joint.

For the support of the plate, a small watch-glass, about three centimetres in diameter, was employed, to one edge of which a thread of glass was fused by a blow-pipe flame, and then bent so as to form a loop by which it could be suspended like the pan of a balance. A small hook of glass was also attached to the side of the thick tube carrying the electrode, and upon this the pan was hung, the loop being so formed as to allow it to swing freely in all directions. The pan, when in place, was about fifteen millimetres below the end of the tube from which the electrode projected, the latter being adjusted to the proper distance by sliding it up or down in its support, as occasion required. By slightly inclining the globe the extremity of the wire could thus be readily brought over any point of the plate. In some of the experiments the plate was stationary, being held in a little tripod of glass threads, or simply laid upon the bottom of the globe. In these cases the tube holding the electrode was jointed near the

top, the two portions being connected by a hook and loop of platinum or magnesium wire. It could thus be made to traverse all parts of the plate by giving suitable movements to the globe.

When adjusted and closed, the receiver was attached to the Sprengel pump. By means of a small air-pump of the ordinary construction, connected with this by a stop-cock and flexible tube, the whole apparatus was exhausted as far as possible and then dry hydrogen admitted, this being repeated two or three times in order to remove the air and moisture. The process of exhaustion was then completed with the mercury pump. The degree of rarefaction required, varied somewhat with the metal to be deposited, but was rarely above 2·5 millimetres. For platinum the best results were obtained, when it was from 1·5 to 1·75 millimetres. The use of hydrogen is not in all cases necessary, as some of the metals can be deposited perfectly well with only air in the receiver. This is especially the case with gold, but platinum, although ordinarily not easily combined with oxygen, becomes tarnished with a film of what apparently is the blue oxide, unless the air is removed. The electrode itself was formed of a small wire, usually not more than one-fourth of a millimetre in thickness, bent at the end into a circle three or four millimetres in diameter, the plane of which was perpendicular to the straight portion of the wire entering the glass tube, and parallel with the surface of the glass plate situated beneath it. Its distance from the latter was generally about three millimetres, though considerable variations were possible. When it is farther away the process of deposition goes on much more slowly, though the results are in most cases quite as good as when it is nearer. After the process of exhaustion was completed, the stopcock was closed, and the apparatus removed from the pump, for greater convenience of manipulation in applying the current.

The electrical apparatus employed consisted of an induction-coil capable of giving sparks four or five centimetres in length, and a battery, the power of which could be varied according to circumstances. It consisted usually of pint Grove cells, from three to six in number, not completely filled, or charged with rather weak acid, and a plunge battery of five cells, of which one, two, or more, were used, as occasion required, the whole being joined in a continuous circuit. By immersing the plates of the plunge battery more or less, as well as by varying the number in the circuit, the strength of the current could readily be changed within the limits desired. The various metals

required currents of different strength, and the power best suited to each had to be determined by trial. It was found advisable in most cases to regulate it so that the temperature of the electrode was below that of a red heat, or such as barely to redden it. Of course with the more fusible metals it was necessarily much lower than this. The metal is actually volatilized by the discharge, as is shown by the fact that the characteristic lines of its spectrum may be seen with a spectroscope, and the film is formed by the condensation of its vapor upon the cooler glass surface. For the production of films with brilliant surfaces, the strength of the current must not be great enough to give the discharge a disruptive character, as this separates some of the metal in the form of powder.

The primary object of the experiments was to obtain films of the different metals upon thin pieces of flat glass for the purpose of investigating some of their optical characters. The apparatus proved to be perfectly successful in its operation, and beautiful films of gold, silver, platinum, and bismuth, were obtained with ease and certainty. As has been mentioned, it seemed probable that the surface of deposit would be dull, but the first trial showed that this anticipation was incorrect, and the films, when removed from the receiver, exhibited surfaces of exquisite perfection and the most brilliant polish. They can only be compared to the surface of clean liquid mercury, far surpassing in lustre anything that can be obtained by the ordinary methods of polishing.

This circumstance suggested at once a valuable application of the process in the production of specula for optical purposes, and the subsequent investigations were directed to this end. The mirrors first made had been formed upon disks of thin glass, such as are commonly used as covers for microscopical objects, those being selected which were most free from defects, and had the best surfaces. By means of a very delicate assay balance, the weight of the glass disks, both before and after receiving the deposit, could be obtained to the one-hundredth part of a milligramme, and hence it was easy to calculate the thickness of the metallic layer in any instance. By this means the relative transparency of the different metals can be determined, and the relation between the amount of light transmitted and the thickness of metal traversed by it. The more particular consideration of these and some other matters of interest as bearing upon the optical characteristics of the metals, is deferred to another time, and

it is only necessary to mention here the results of some measurements which were made in order to determine the limiting thickness of a film in regard to the transmission of light; that is, the thickness of a film which would allow only an inconsiderable proportion of the incident rays to pass through. As the metallic lustre is developed gradually with the increasing amount of metal, showing conclusively that light actually penetrates these substances to a certain depth, it was important to ascertain whether the thickness of the layer, sufficient for a virtually complete reflection of light, would be great enough to affect perceptibly the figure of a mirror of glass upon which it was laid down.

Experiments for this purpose were made with gold and platinum, and the process of deposition was continued until the films appeared to have just reached the condition of complete opacity. On removing them from the receiver, however, it was found in both cases that a very small amount of light was still transmitted, as on holding them close to the eye, a brilliant object, like the sun or a bright flame, could be seen through them. The thickness of the gold layer was found to be 0·000183 mm., that of the platinum 0 000174 mm., or approximately one-fourth the length of a wave of light at the red end of the spectrum. The gold, although thicker than the platinum, transmits perceptibly more light, showing that it is the more transparent of the two metals. As the films employed for mirrors may be much thinner than the amount mentioned without an appreciable diminution of the intensity of reflected light, it is evident that the figure of a perfectly wrought glass mirror will not be changed, when the metal is uniformly deposited, to such an extent as to affect its performance unfavorably. A platinum film of one-fifth the thickness of the one described, forms a brilliant mirror, transmitting but a very small percentage of light. The perfect control of the process obtained by the use of the movable electrode will even make it possible to apply the method of local correction for the improvement of a defective figure, or to parabolize a spherical mirror by depositing the metal in a layer increasing in thickness toward the centre, though, of course, it would be better to avoid a somewhat tedious operation by securing the perfect form of the glass beforehand.

Of the metals that are suitable for the formation of specula, platinum appears to be the most valuable. For while, when well polished, it is but little inferior to silver in reflecting power and freedom from

color, it does not become tarnished by oxidation or the action of sulphurous gases, and when dulled by atmospheric deposits the surface can be cleaned by washing with water or with acids, which is an important advantage. By the method here described it can be deposited upon glass surfaces very easily, and a mirror of the most perfect surface produced at once, without the necessity of a single touch to complete it. Several such mirrors have been made in the course of these experiments, by the use of concave glass lenses, with the most satisfactory results. The metal film adheres strongly to the glass, and when of sufficient thickness appears to be very firm and hard. In mirrors silvered by the ordinary method, trouble is often experienced from the insinuation of moisture between the glass and the metal, resulting finally in the separation of the latter. In those prepared by the new process the adherence of the film is so close as to render such an effect impossible. As a test of this, a small silvered speculum was placed in a beaker of water, where it remained for two weeks, and besides this was wetted and dried repeatedly, without showing the slightest tendency to suffer the penetration of the moisture. Similar results were also obtained with platinum and gold films.

With silver the process likewise succeeds well, but it is more difficult to obtain good surfaces than with gold or platinum. The metal is volatilized with extreme ease by the action of the current, and the energy of the discharges must not be too great. Of several trials made with this metal, the most successful was one in which not only the degree of exhaustion of the receiver was less than had been employed in other cases, being only to three millimetres, but the electrode was more distant from the plate, and the battery weaker. The action proceeded slowly in this instance, but with the result of producing an excellent film. With a stronger current the deposit is rapidly made, and has a fine lustre, but the surface has a yellowish color. This is perhaps partially due to a slight degree of oxidation, but also appears to be owing in part to the deposition of a portion of the metal in the form of fine powder, the vapor of the silver, as it streams from the electrode toward the more distant portions of the plate, becoming partially condensed, and falling on it in minute particles. That such a result would follow from this cause, was shown by some of the experiments in which a rather strong battery was employed. The whole interior surface of the globe was in a short time covered with

the powdered metal, appearing an intense purple where thinnest, and shading gradually to deep blue where thickest, the color being the same by both transmitted and reflected light. The metallic lustre was wanting, though it was readily developed when a portion of the powdery coating, which was easily removed, was rubbed against the surface of the glass with some pressure. The defect was, to a considerable extent, remedied by surrounding the electrode with a small glass tube projecting some three millimetres beyond it, so as to clear the surface of the plate by an interval of only one or two millimetres. This had the effect to cut off the lateral portion of the discharge, and to confine its action to a limited area immediately below the extremity of the wire.

The yellow tarnish is removed with the greatest ease by gently rubbing the surface with soft chamois leather and a little rouge, and the metal is so hard, that, when this operation is performed with care, the polish is not at all, or but very slightly, affected. Even then, however, the metal is not perfectly white, having still a very faint yellow tinge. It is well known that silver is not a perfectly white metal, for light which has undergone repeated reflections from polished surfaces of this metal appears yellow or reddish-yellow, though this color is not perceptible when the light has undergone but a single reflection. But the real cause of the yellowish tint may possibly be found in the very tenuity of the films, which, when prepared in this way, have a beautiful and intense blue color by transmitted light. When not too thick, the amount of blue rays which they suffer to pass, may be sufficient to cause, by their abstraction, a perceptible tinge of yellow, the complementary color, in the reflected rays. If this were really the case, the coloration should grow weaker with an increase of thickness, and disappear when opacity is reached. Some of the results obtained seem to favor this view, and the probability of its correctness is strengthened by the facts related in the next paragraph, but further experiments are needed to decide the question satisfactorily.

One result of the investigation has been to show that the color of the light which has passed through a layer of metal varies somewhat with the thickness of the film. This was known to be the case with gold, and experiment has shown it to be true of platinum and bismuth also. Thus the latter in a very thin film appears a clear bluish-gray, while a much thicker film appears brownish. Platinum in a thin layer

has a grayish tint, which varies, as the film is made thicker, to a peculiar brownish shade, somewhat like that of sepia, passing into brownish-yellow, and finally becoming a deep yellow, even inclining somewhat to orange, in the thickest films obtained. Now this color is almost exactly complementary to that transmitted by silver, and the possibility suggested itself of making a mirror which should be perfectly white by reflected light, by depositing first a thin stratum of silver, and over this another of platinum, the relative thickness of the two being properly regulated by observing the color of the transmitted light. An experiment made with a circular disk of flat glass was perfectly successful, the platinum being readily deposited upon the silver, the yellowish tint of which it entirely removed, producing a white and brilliant reflecting surface. By transmitted light the film, as it was anticipated would be the case, has a pure neutral tint, with no perceptible color of any kind.

The value of such a combination for specula is evident, for though, until careful measurements are made, it cannot be asserted that the absolute reflecting power is increased, the whiteness of the layer, and the protection afforded by having the surface covered with an unalterable metal, are very substantial advantages. In constructing large mirrors it will probably also be found to result in a material saving of time, the silver being so much more rapidly and easily deposited than the platinum. The process can also be used with great advantage for the construction of solar eye-pieces for telescopes, since the compound film can be deposited directly upon the surface of the lens, and made thick enough to reduce the intensity of the light as much as may be desired. An image, nearly or quite colorless, could thus be obtained, and the disturbance of the rays should be less than that produced by the interposition of a dark glass of the ordinary kind.

As has been mentioned, some experiments were made with bismuth, and a mirror of excellent surface was obtained, but the metal is inferior to platinum in brilliancy, and has a decided color. The great facility with which films are obtained with it might recommend its use for mirrors in some cases, but for most purposes other metals are to be preferred. Attempts to produce mirrors of iron and nickel were but partially successful, as it was difficult to prevent tarnishing by oxidation. Some good iron films were obtained, however, which were very brilliant. They were exceedingly hard, and adhered to the glass with such tenacity that at first it seemed as if they had been

fused into it. But when the film was dissolved off by an acid, the glass was found not to have been acted upon at all. A singular characteristic of the iron in this condition is its chemical inertness. Films prepared more than six months ago and freely exposed to the air, which, for a part of the time too, was excessively charged with moisture, have not shown the least alteration. Nitric acid, placed upon one of them for a short time, produced scarcely any effect, and nitro-hydrochloric acid acted upon it with about the same readiness as it does upon platinum. This may be due to the extreme thinness of the film, in consequence of which, even the exterior atoms of the iron, being within the range of the molecular action of the glass, are held by a force tending to oppose and neutralize the attraction of reagents that ordinarily attack the metal energetically.

It is not at all necessary that the object upon which the metal is deposited should be of non-conducting material. This is shown by the fact that the process continues to go on after the glass has become covered with a perfectly continuous layer of metal of considerable thickness. The success of the experiment of covering a silvered glass with platinum is additional evidence of the same fact. In order more fully to test the question whether a deposit could be made upon a solid piece of metal, a small silver coin was placed in the pan under an electrode of gold. It was covered in a few minutes with a beautiful coating of the latter metal, which was found to be very hard and to adhere perfectly, having also, in every respect, its proper color and lustre. At the beginning of the process, while still thin enough to allow light reflected from the silver to pass, it had a greenish color, producing a curious effect.

As an example of the applicability of the process to practical purposes, it may be of interest to mention the results of some experiments in the construction of a small Gregorian telescope, the specula of which were covered with platinum by the method described, and with entire success. The larger mirror has a diameter of a little less than four centimetres, and both this and the smaller one, so far as the nature of the surface is concerned, appear absolutely faultless. As only common lenses were employed in its construction, the performance of the instrument is not remarkable, but it is sufficiently good to warrant the assurance that the method will be serviceable for the production of specula of exquisite quality for optical purposes. The size of the apparatus, which, for convenience in experimenting, was neces-

sarily small, did not permit the introduction of larger mirrors than this, but there seems to be no reason for doubting that much larger specula can be successfully made in this way. The amount of time required for obtaining the platinum covering of this mirror was about three hours, during which the coil was kept in continuous action, with a battery power equivalent to four or five small Grove cells. Mirrors of larger size would of course require a longer time, but with suitable apparatus a much stronger battery and larger coil could be used, which would materially accelerate the operation. A plate two centimetres in diameter can be covered with platinum in twenty or thirty minutes sufficiently thick to form a good speculum. For gold or silver the time would not be more than from ten to fifteen minutes.

Many useful applications of this process may be found, and its use is not limited to those metals which have been mentioned here. Moreover, for many of them no other available process is known by which they can be deposited in a uniform layer and with a brilliant reflecting surface upon glass. A very thin layer of platinum, or, still better, of silver and platinum together, could be used with great advantage in the *camera lucida* and similar instruments. Very perfect mirrors for galvanometer needles, and for delicate torsion apparatus, can be expeditiously formed in this way, and by the use of very thin glass, or the most delicate films of mica, they may be made of almost inappreciable weight. For the mirrors of heliostats, and other reflecting instruments in which a metallic surface is necessary, the specula produced by this method will be especially valuable. For telescopes, the beautiful process of Liebig and Foucault, for forming silvered glass specula, is recommended by the ease with which it is applied, and the rapidity of its operation. But the perishable nature of the delicate silver film, and the difficulty of securing a firm and permanent adherence, are serious disadvantages. These are entirely avoided by the use of an unalterable metal like platinum; and though for instruments of the largest size the process here described may be found impracticable, for those of more moderate dimensions there is every reason for believing it may be employed with complete success. The labor and time required for its application are indeed drawbacks; but there is compensation for this in the important circumstance that the mirror comes out of the receiver with a surface of inimitable perfection, which would, in fact, only be injured by any of the ordinary methods of polishing.

ON A NEW TYPE OF STEAM ENGINE, THEORETICALLY CAPABLE OF UTILIZING THE FULL MECHANICAL EQUIVALENT OF HEAT-ENERGY, AND ON SOME POINTS IN THEORY INDICATING ITS PRACTICABILITY.

Presented at the Nashville meeting of the American Association for the Advancement of Science, 1877.

By Prof. Robert H. Thurston, Vice-President.

I.—It is easy to show that the existing common type of steam engine, even if perfect as a piece of mechanism, necessarily wastes a very large proportion of the heat-energy which is supplied to it, and that no possible improvement short of a complete change of type can greatly increase the efficiency of the best modern engine.

A steam engine, theoretically capable of fully utilizing the heat-energy supplied, and of delivering the mechanical equivalent of that heat, has never yet been constructed. The possibility of constructing such an engine has been denied by both physicists and engineers. Nevertheless, theoretically perfect air and gas engines have been designed and built, and a steam engine can probably be made, which may fully utilize all heat not lost by conduction, radiation, and friction. The object of the present paper is to show, not only the possibility of designing such an engine, using steam as the working fluid, but also the probable practicability of constructing a machine which shall waste no heat, except by conduction and radiation, and no power except by friction, under conditions which the engineer will admit to be attainable.

The theory of the proposed new type of engine is perfectly simple; and its construction, although involving the overcoming of grave difficulties in the reduction of losses by friction to a satisfactory extent, may possibly prove no more difficult a problem, than have been many others already solved.

The working fluid is assumed to be steam, because the proposed type of engine cannot be adapted for use with the permanent gases without special and undesirable modifications.

II.—A very simple conception, originating with Sadi Carnot, who published it in his well known work on Heat, half a century ago,[1] has

[1] *Reflexions sur la Puissance du Feu;* Paris, 1824.

furnished a basis upon which has been established the test of a perfect heat-engine. In applying this test, it is necessary to follow the operation of the engine through a complete cycle. The cycle embraces a succession of changes, which concludes by the return of the system to the precise set of conditions with which the cycle commenced. Such a cycle is a *closed curve of conditions.* It is only possible to infer the real relation existing between the heat-energy imparted to any machine and the mechanical energy developed from it after the working fluid, used as a conveyor of the heat-energy in that machine, has been restored, after experiencing a complete cycle of changes, to its primitive condition. The heat-cycle usually corresponds to a kinematic cycle in the engine itself.

During each complete cycle, a certain amount of heat-energy is supplied to the machine, and a certain other amount of mechanical work is done by the machine upon external objects and upon its own moving parts. The result is the accomplishment of a certain amount of useful work, and the consumption, or, more properly, the conversion, of a definite amount of heat in doing that work. Let these two quantities be called A and A'.

Imagine the engine reversed and to complete a cycle in the opposite direction. If the engine be "perfect," every operation is, during this inverted cycle, given a negative direction, and the net result is the re-conversion of the heat A', from the equivalent mechanical energy, A, which is expended in driving the engine backward. An engine capable of reversion in this manner, and with such a result, is a perfect engine and yields the greatest possible amount of mechanical energy from the heat supplied to it.

For, if not, suppose it coupled to an engine which is more nearly perfect, *i. e.*, requires less heat to do a given amount of work. Then suppose the first driven backward by the second. The former restores heat to the source from which the latter receives it. The amount restored is the full mechanical equivalent of the work expended in reversing the assumed imperfect engine. But the heat required by the more perfect machine, which does that work, is less than that amount, and it consequently follows that there must be an accumulation of heat in the reservoir, which heat must have been the product of actual creation—a *reductio ad absurdum.* It follows, therefore, that the reversible engine is a perfect heat-engine, and will yield the full mechanical equivalent of all heat which it is theoretically capable of utilizing.

It follows from the principle of the "conservation of energy," that if a certain quantity of energy is communicated to a system at the commencement of, or during, a cycle, no part of that energy can be extinguished. It must all reappear during the cycle in some form, before the completion of the cycle. In the heat engine there is no known way in which heat-energy can be expended, except by the production of mechanical energy, by loss in friction, and by dispersion by conduction and radiation from the system. In all heat engines, any heat not disposed of in these ways will reappear in its original form of heat-motion.

A perfect engine, therefore, in the sense in which the term is here used, is one in which no heat is lost by conduction, radiation or friction, and in which all heat not discharged unused at the completion of the cycle is utilized by conversion into mechanical energy which may be usefully applied.

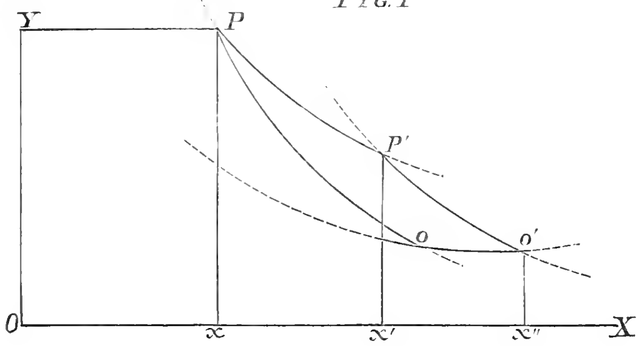
Assuming those conditions which are known to be invariable where the permanent or perfect gases are used as working fluids, to be equally invariable with all working fluids, it is easy to determine, by the application of the principle of Carnot, what is the efficiency of a perfect engine working under any given set of conditions as to temperature. Carnot's conception was, to a certain extent, faulty, in consequence of the fact that, in his time, the character of heat-mo-ion was not understood, the doctrine of the persistence of energy had not been taught, and the science of thermo-dynamics had not taken shape. Sir Wm. Thomson, in 1849, modified the conception of Carnot in accordance with the now well known laws of thermo-dynamics, and gave us the perfect test of the perfect engine.

III.—In illustration, conceive a working cylinder and piston, made of some absolutely non-conducting material. Let the variation of pressure and volume of the working fluid in this cylinder during a single cycle—a double stroke of the piston—on one side of the piston be represented in the accompanying diagram, as in the indicator diagram obtained by Watt from actual steam engines at the end of the 18th century, and as in the theoretical diagrams given by Clapeyron, in 1834. This is such a diagram as would be produced by a pencil moving horizontally with the piston, and at the same time having a vertical motion, proportional to the magnitude of the pressure of the working fluid within the cylinder.

Thus, in the figure, the length of the stroke of piston is measured on the diagram by the distance from the abscissa of the point P to that of the point o'. The pressure varies from that corresponding to the ordinate of P to that of o'. The area of the figure, $P\ P'\ o'\ o$, is a measure of work done.

Suppose the cylinder to contain a certain volume, $O\ x$, of an expansible fluid at the pressure $P\ x$. Let it expand, driving the piston before it and doing work against a varying resistance. Supply to the fluid a quantity of heat, just sufficient to compensate the loss by transformation into mechanical work. The fluid is thus retained at the original temperature, and the curve of varying pressure will be

FIG. 1



an isothermal curve. From the point P' let the fluid expand without receiving heat from any source; it will now lose heat by transformation into work, and its temperature will fall, the line becoming an adiabatic curve, as such a curve has been named by Rankine. At o', reverse the motion of the piston, and remove the heat due to the compression of the working fluid as rapidly as that heat is produced. The pressure line now becomes $o'\ o$, and is an isothermal curve. Let the removal of the heat of compression cease at the point O, which point is so situated that the final return of the piston to its starting point will bring the pressure line, now again adiabatic, to P, and thus restore the fluid to its original condition, as to both temperature and pressure.

Such a cycle can evidently be reversed, each operation occurring in reverse order, and in the reverse direction, and any engine of which this is a representative cycle, is a perfect engine.

IV.—Carnot showed that the maximum efficiency—the maximum proportion of heat utilized to heat supplied—in the perfect gas engine, when the engine transfers heat from a source having an absolute temperature, t, and discharges unutilized heat at a lower absolute temperature, t', is a fraction equal to the ratio of the range of temperature to the maximum temperature:—

$$E = \frac{t - t'}{t}.$$

Benjamin Thompson, Count Rumford, in 1798, indicated the true nature of heat, and by experiment obtained an approximate measure of its mechanical equivalent, which was corrected by the later experiments of Joule, 1843 to 1849. Sir Wm. Thomson, in 1848, showed that we have an absolute measure of temperature (and of heat also, where no physical change of state occurs) in a scale of which the zero is situated 493·2° Fahr., or 274° Centigrade, below the melting point of ice under atmospheric pressure. In any fluid, no change occurring in its capacity for heat with change of temperature, the quantity of heat present in the mass is proportional to its absolute temperature. The mechanical equivalent of heat is now universally taken as 772 foot-pounds of energy per British thermal unit, and as 424 kilogrammetres per metric thermal unit, or *calorie*. These facts furnish us with a means of determining the theoretical efficiency of engines of perfect types working under specified conditions. All existing heat engines are imperfect in proportion as they waste energy by the conduction and radiation of heat to external bodies, and as they waste mechanical energy by friction; since, on reversal, the energy lost in these directions cannot be gathered up by the machine and restored to the source. The heat engine is also, in a certain sense, imperfect, because it is usually the fact that heat rejected unutilized is all lost, and cannot be restored to the source from whence it was supplied to the engine. In some forms of heat engines, a part of this rejected heat is so restored.

V.—Whenever, as is the case with steam, a working fluid experiences a change of its physical state, which results in a change of its specific heat while in the engine and doing work, such estimates of efficiency become only approximate. To secure an accurate measure of efficiency, it is necessary, if Thomson's absolute scale of temperatures is retained, to construct a special thermometer for

each substance, on which the degree must have a different magnitude for each as measured by the ordinary thermometer.

Carnot's unqualified statement, is not, therefore, correct. It is not true that the efficiency of a heat engine is simply "a function of the two limits of temperature between which the engine works, and not of the nature of the substance employed." This is only true when the specific heat remains constant between those limits, and down to the absolute zero. As the specific heat is not always thus constant, it is a matter of importance to consider the nature of the substance used as a working fluid in any case.

When such changes of physical state occur after the working fluid is rejected, they have no importance, except, as will be seen presently, so far as they have a bearing upon the effect of modifying the type of engine.

VI.—Applying the principles which have now been stated to the determination of the maximum possible efficiency of the most perfect of existing steam engines, and comparing the result with the efficiency actually attained, it is easy to determine to what extent improvement is possible without change of type.

Heat engines may be divided, for present purposes, into three principal classes, according to their disposition of rejected heat:

1. Those which restore all heat rejected from the working cylinder to the reservoir from which it was derived.

2. Those which restore a part of the unutilized heat of the working fluid, discharging the remainder from the system and allowing it to be wasted.

3. Those which waste all heat rejected from the working cylinder.

No existing type of steam engine belongs to the first of the classes specified. Some forms of air and gas engines are theoretically assignable to that class, as, by means of some form of "regenerator," they store up rejected heat and restore it to the succeeding charge of working fluid as it enters the cylinder. Actually, however, these engines cannot perform this part of their task thoroughly, and they are thus really to be catalogued in the second class.

Nearly all heat engines, including the steam engine, are most correctly assignable to the third class. In the steam engine, the rejected heat, on leaving the steam cylinder, is thrown into the condendser or discharged into the atmosphere, and, in either case, is wasted. A small portion is usually saved by supplying the boiler

from the hot-well or from heaters in which it has acquired some increase of temperature by transfer from exhausted steam. In so far as this takes place, they fall into class 2. They will here be considered as belonging to class 3.

All actual steam engines may therefore be considered as belonging to one primary class. They all take steam from a source having a high temperature, degrade the heat thus obtained to a lower temperature, doing work and consuming a definite amount of heat in the production of a definite amount of mechanical energy, and finally discharge unutilized heat into the atmosphere or into a large volume of condensing water, by which it is carried out of the system and thrown away.

VII. The steam engine differs radically from air and gas engines of its own class in one respect; and this difference, although passed over as apparently unimportant by accepted authorities on the theory of the steam engine, has constituted a serious and hitherto unsurmounted difficulty in the process of calculation of the exact efficiency of the steam engine.

With all heat engines in which the working fluid experiences no change of physical state, as, for example, in the air and gas engines, we have

$$\frac{t-t'}{t}=\frac{Q-Q'}{Q},$$

the quantities of heat being proportional to the temperatures on the absolute scale. The same is approximately, if not absolutely, true of superheated and of dry steam. It is true, with sufficient exactness for the purposes of the engineer, of water. The proportion is not retained, however, in the fluid which actuates the steam engine —a mixture of steam and water in which the proportions of the two fluids are difficult of determination, if not absolutely indeterminate, at the commencement of the stroke, and in which the proportions are constantly changing throughout the stroke of the piston.

The varying specific heat of the mixture, and the variation in the amount of work done, might be more satisfactorily estimated were it not for the peculiar methods of waste of heat which are characteristic of the steam engine, the most important of which are the internal condensation and re-evaporation, which will be more fully described presently.

Assuming, however, for the moment, that the steam cylinder is made, as in the typical engine of Carnot, of non-conducting

materials, a given amount of steam, entering it at a temperature and volume such that the work done before expansion commences is equal to $p\ v$, is permitted to expand normally, the curve of pressures following, approximately, a line nearly hyperbolic.

As the specific heat of saturated steam is negative, a portion of the charge is gradually condensed as expansion goes on and work is done, and there is finally discharged from the cylinder a mixture of steam and water, the water bearing a higher proportion to the steam remaining as the work of expansion is greater.

But this mixture of liquid and vapor contains, usually, vastly less heat than an equal weight of steam at the same temperature. In any gas engine, $t : t' = Q : Q'$; but here the proportion does not hold, and we have, for steam,

$$\frac{Q - Q'}{Q} > \frac{t - t'}{t}.$$

Hence, the steam-engine *should be* more economical than the air or gas-engine working between the same limits of temperature. That it is not, can only be due to the cause of loss already adverted to as peculiar to the steam engine; or, more correctly, to heat engines, in which the working fluid changes its physical state within the working limits of temperature and pressure. In consequence of the facts just stated, it is seen that the usually accepted method of estimating economy, as in gas engines, is not correct as applied to the steam engine.

VIII.—Neglecting the inaccuracy arising from the peculiar action of steam in the engine, as just described, we will make an approximate determination of the maximum efficiency of the perfect steam engine of the best existing type, and working between the widest limits of temperature generally and successfully attained.

A marine compound engine of the most successful type in general use, takes steam from the boiler at a pressure of 90 pounds per square inch above a vacuum, and discharges the exhaust steam into a condenser having a temperature of 126° Fahr. (53° Cent.), and at a pressure of about 2 pounds per square inch. The original temperature of the boiler steam was 320° Fahr. (160° Cent.) The efficiency should then be:

$$\frac{320 - 126}{781{\cdot}2} = \frac{160 - 53}{434} = 0{\cdot}25 +.$$

It should do $772 \times 0{\cdot}25 = 193$ foot-pounds of work for each British thermal unit of heat supplied to it. Per hour and per horse-power of 1,980,000 foot-pounds, it would demand about 10,000 heat units, which would be supplied by the combustion of a pound of coal, evaporating 10 pounds of steam—a very usual and a very good rate of evaporation for steam boilers. Could all of the heat supplied to the engine be fully utilized, however, it would do its work with one-fourth of this consumption of fuel—on $2\frac{1}{2}$ pounds of steam per hour and per horse-power, using $\frac{1}{4}$ pound of coal. But even this estimated efficiency does not represent the full theoretical economy of an ideal steam engine, since, in consequence of the fact already adverted to, that the specific heat of the mingled steam and water, which forms the working fluid, is continually changing as expansion proceeds; and, therefore, the real efficiency is greater than here estimated. This difference becomes very great with great expansion. We may, therefore, say that the perfect steam engine, working under the assumed conditions, would work on considerably less than 1 pound of coal per hour and per horse-power.

The average performance of the best engines built to-day, to work through the assumed range of temperature and pressure, does not even approximate to the calculated efficiency of the perfect engine. The latest and best type of compound engine, taking steam from the boiler at 75 pounds pressure by gauge, and exhausting its steam at a temperature approximating that assumed in the above calculations, requires, usually, about 20 pounds of steam, or, say, 2 pounds of coal per hour and per horse-power. Good engines as now built, therefore, waste at least one-half the heat which is theoretically *available* for the production of power in the existing type of steam engine.

IX.—Now, attempting to apply the test of Carnot and Thomson, we may detect the defects of the machine, and learn what are the causes of loss of all this wasted power:

Tracing the operations which constitute the cycle of the machine in reverse order and direction, we find that such an inverted cycle must include the collection and restoration of all that heat-energy which has been discharged into the atmosphere or into the condensing water at the end of the stroke of the piston; the collection and restoration of all heat which has been lost by radiation and conduction to surrounding bodies; and the reconversion into available heat of all work lost in friction. All this is manifestly impossible in the

existing type of engine, and it is equally evident that the methods of reducing these losses—which are, to a certain extent, inevitable—by friction, and by conduction and radiation, are well known, and are applicable to engines of every conceivable type.

The sources of loss are, then :

1. Friction.
2. Conduction and radiation of heat.
3. The rejection of unutilized heat in the exhaust steam.

The first two of these methods of loss are comparatively unimportant, and, by proper management, can be reduced to a very insignificant amount. It is the last named cause of loss of work that is to be studied, with a view to the determination of some method of greatly increasing the efficiency of the steam engine.

X.—The rejected heat which is exhausted from the engine at the end of each stroke, consists of two parts:

1. That which, in the example above given, constitutes about three-fourths of the heat supplied, and which, in consequence of the natural distribution of the heat throughout the scale of temperature, is necessarily always lost in this type of engine.

2. That which, by the operation known as condensation and re-evaporation in the steam cylinder, is transferred from the steam chest to the exhaust side, at each stroke, without doing its share of the work of the engine.

The method of the first loss of heat has already been indicated with sufficient clearness. The second loss occurs in a way which has but recently become well understood, and which is still not clearly comprehended by many even professional engineers. It is, however, easily explained.

When steam expands in the steam cylinder, it enters at a comparatively high temperature, and at the end of the stroke, at the lowered pressure, has a considerably decreased temperature. There is therefore a tendency, which sometimes has a marked effect, to produce similar changes in the temperature of the cylinder itself—heating it at the entrance of the steam, and cooling it as expansion progresses. The greater the expansion, the greater is this variation of temperature. With considerable expansion, it becomes very great, and, the metal of the cylinder being affected to some depth, the amount of heat passing back and forth between the steam and the

metal is often a very large proportion of the total heat of the entering steam. When, therefore, saturated steam enters the cylinder, it finds the interior surface of the metal comparatively cool, its temperature having been reduced by contact with the exhaust steam just rejected from it. Condensation, therefore, occurs and continues until a sufficient amount of heat has been transferred from the entering steam to the metal of the cylinder, to restore it to the temperature of the prime steam. Thus it is invariably the fact, when superheating is not practiced, that the steam cylinder, at the instant of closing the steam valve, contains both steam and water. The relative amount of the two fluids varies greatly, but it is usually found, where considerable expansion is adopted, that the weight of water is quite great. After the closing of the induction valve, and as expansion progresses, the water, originally at the temperature of its boiling point, under boiler pressure and that of the entering steam, finds itself under a constantly decreasing pressure. Re-evaporation, commencing with the first decrement of pressure, goes on regularly, until the expansion is brought to an end by the termination of the stroke of piston and the opening of the exhaust valve. During this re-evaporation, the water can only obtain its latent heat of evaporation by robbing the surrounding metallic surfaces, after absorbing from the supernatant steam any slight excess of temperature above that due its pressure, which the latter may have itself taken from the metal of the cylinder during that period of rapidly decreasing temperature and pressure which immediately succeeded the commencement of the expansion. Finally, at the opening of the exhaust valve, a sudden drop of pressure occurs, and the whole mass of mingled steam and water remaining in the cylinder at once expands into the condenser, or into the atmosphere, and the re-evaporation of water, which now occurs in great quantity, makes another draft upon the cylinder, reducing its interior to, approximately, the temperature of the condenser or of the boiling point, under atmospheric pressure. Thus heat is taken into the metal of the cylinder from the "live" steam at the beginning of the stroke, and transferred to the exhaust steam, and thrown away without conversion into work. The heat absorbed in re-evaporation before the exhaust takes place, is partly utilized; but that which is taken up at the opening of the exhaust valve, is wholly wasted.

The process of waste just described is one of the most serious causes of loss of heat in the modern steam engine; in some cases, the loss from this cause exceeds that due to the unavoidable rejection of heat at the lower limit of temperature, which only is taken into account in all accepted theoretical estimates of efficiency. It is this method of waste that prevents the engineer acquiring even an approximation to the estimated gain due to considerable expansion. It is this which places a limit to our expansion of steam, which limit has, as yet, been but little altered by any of the expedients which have been adopted to extend it. It has been found by experience that with steam of 60 or 70 pounds pressure, no gain in efficiency can usually be secured by expanding more than five or six times. Passing this limit, the losses due the wasteful transfer of heat to the exhaust steam increase much more rapidly than the gain due to the increased conversion of heat into work by expansion.[1] The higher the steam pressure and the greater the speed of piston, the less the loss from the operation of this cause. The use of superheated steam also reduces it. When the steam is so far superheated that the mass taken into the cylinder may surrender to the metal all the heat required to warm it up to the temperature due the steam pressure, without itself falling to the temperature of saturation at that pressure, this loss is reduced to a minimum. But the saving is effected at the sacrifice of some theoretical efficiency. Steam jacketing produces its well known benefit by checking the waste due to this condensation and re-evaporation.

The losses by the rejection of heat from the engine without transformation are thus seen to be due to two entirely different causes: the first, which is always a proportion, $\frac{Q'}{Q} \times U$, of the total heat supplied, can evidently only be saved by some radical change of type of engine. The second, which has been diminished, but has never been wholly checked by known expedients, seems very probably to require equally radical treatment to effect its cure. It is perfectly evident, nevertheless, that to secure any great increase in the efficiency of heat engines in which steam is to be used as the working fluid, some change must be made by which these losses must be avoided; it is

[1] In general, the number of times which the volume of steam may be expanded in the high-pressure engine with maximum economy, is not far from $\frac{1}{2}\sqrt{P}$, where P is the pressure in pounds per square inch; it rarely exceeds $0{\cdot}75\sqrt{P}$.

only then by a change of type that the now usual loss of nearly three-fourths the heat by rejection at the lower limit of temperature, and of a very large fraction of the remaining energy, can be, to any considerable extent, prevented. Could a change of type be secured by which all this heat could be utilized, giving a theoretical efficiency of unity, we might expect an actual efficiency of at least one-half, and thus obtain a horse-power by the expenditure of five pounds of steam, and the combustion of a half pound of coal per hour. The best existing type of engine has been seen to demand four times this amount, and it is very common for engines to require ten times as much.[i]

XI.—It now remains to be determined whether there is any way by which these losses of rejected heat can be avoided.

There are two forms of engines of class 1st, in which—were it possible to fully avail ourselves of them—all this waste of energy may be avoided:

Type A. The working fluid, if expanded from the temperature and pressure of the boiler or reservoir quite down to the absolute zero, would have all its heat-energy transformed into mechanical work, and there would be no waste. The efficiency would be perfect.

Type B. All heat rejected from the cylinder unutilized may be gathered up and restored to the boiler, there to serve as a basis upon which to pile a new stock of transformable heat-energy, instead of being, as now, rejected from the system entirely and lost. This done, there could be no loss, as all heat leaving the machine would be transmitted to exterior bodies as mechanical energy. Nothing being lost as heat, the efficiency of the engine would be unity and its economy a maximum.

Forms of steam engines may be conceived in which these methods (of saving heat now wasted) may be applied. Practically, however, it is evident, the first form of these two ideal engines can never be made successfully, since it would require to be made of such immense size that all the power derivable from it would be insufficient to move

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[i] Good engines should not require more than $W = \frac{200}{\sqrt{P}}$, where W = the weight of steam per hour and per horse power; the best practice gives about $W = \frac{150}{\sqrt{P}}$ in large engines with dry steam, high piston speed, and good design, construction and management.

the engine itself. The great expansion of steam necessary to secure the reduction of the mass to the liquid state, even—to say nothing of the probable impossibility of making heat contained in the water available—would compel the adoption of cylinders of such great volume as would prevent the adoption of such engines. All advantage theoretically derivable from their use would be more than neutralized by the immense frictional resistances to which they would be subject, even were it possible to construct them.

It is also evident, at once, that this objection would be met, but in a less degree, with engines of the second of these two forms, and that the difficulty would be diminished by extending the range of working temperatures and pressures, and also that it would be lessened by any modification which should reduce the proportion of rejected heat. It follows at once that the direction in which we should look for improvement is that in which the well known expedients for increasing the economical value of the common type of engine may be adopted, with the addition of the single expedient here described of saving and returning to the reservoir all rejected heat after its amount shall have been reduced to a minimum by those familiar methods.

XII.—It is not at all impossible that, although the first of these newly proposed types of steam engine is unlikely to have practical value, a modification of that type may, at some future time, come into use and effect a considerable saving of the now wasted heat. It seems improbable, yet it cannot be said to be impossible, that the first method may be carried so far as to secure the greater part of the heat now rejected in the form of latent heat, and that thus only the heat rejected in the liquefied steam will be wasted. Experiment has not yet determined fully, either the law of distribution of heat throughout the scale of temperature, in either water or steam, or the method of change of physical state. It cannot, therefore, be said whether the peculiar and irregular changes of condition of the fluid, which are observed within the range of temperature familiar to us, are illustrations of similar, and possibly more marked, irregularities of physical modification of temperatures nearer the absolute zero or under pres sures, which Dr. Andrews, and other physicists, and Perkins, Alban, and others, among engineers, have barely begun to study.

We therefore cannot say what would be the behavior of the fluid in an engine of the first type, and cannot even imagine how far the theory of efficiency of heat engines, as usually accepted, may apply

to the steam engine of the now standard type, when the range of temperature of its working fluid shall have been greatly extended. It does seem probable, however, that the steam engine will be found to have a theoretical efficiency, greater than we have previously supposed; and we hope that the practical difficulties to be overcome in the attempt to realize that maximum economy, will be also found to be less than has been anticipated when they are resolutely attacked.

XIII.—It is evident that an engine of class A can only exist when expansion can be carried to such an extent as to leave the working substance at the absolute zero of temperature and entirely deprived of all actual energy.

But Sir Wm. Thomson has enunciated the principle:

"It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter, by cooling it below the temperature of the coldest of the surrounding objects."[i]

Were this principle universally true, it is evident that no engine could be constructed in which the working fluid could be degraded to an average lower temperature than the mean annual temperature of the earth at the latitude of the place in which the engine should be situated. Clerk Maxwell has pointed out the fact that, by a peculiar conceivable, though impracticable, device, the limit fixed by this principle may be exceeded.[ii] It is also easy to conceive a much simpler and more natural set of conditions, as will be presently seen, which will permit the limit to be passed, and, possibly, the practical limit to be set back indefinitely in the direction of the zero of heat-motion.

In truth, the principle, as stated, is not correct, except as it implies the existence of certain conditions which are practically persistent, including the use of a permanent gas as the working fluid, or of a substance which does not change its physical state in such a manner, during the conversion of heat into mechanical work, as to invalidate the asserted law.

The fact is, that the conversion of heat-motion into mechanical energy is not limited theoretically, and *may* not be limited practically, by the temperature of the earth's surface.

[To be continued.]

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i On the Dynamical Theory of Heat, etc., by Wm. Thomson; *Trans. R. S. E.*, March and April, 1851.

ii *The Unseen Universe*, pages 88–89.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[i]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. civ, page 208.]

The hot gases from the pyrites kilns are often used for the concentration of sulphuric acid. In this case the leaden pans are placed above or behind the kilns, or the sulphurous acid from the furnaces is passed into a lead tower filled with hard burnt bricks. The arrangement of pans upon the kilns has the disadvantage that if they leak the escaping acid destroys the furnace. It has repeatedly occurred that in cases of such construction the manufacture of sulphuric acid has had to be suspended at the end of the year, and the pyrites kilns entirely rebuilt. It is preferable to place the pans behind the furnace, and to construct a subsidiary flue connecting the kilns with the chamber, so that if repairs in the pans become requisite, the manufacture of sulphuric acid may still go on without interruption.

A much better utilization of the hot sulphurous acid for the purpose of concentration is effected in Glover's tower, which was first introduced in England, and has been described in full by Lunge.[ii] The so-called Glover's tower consists of a leaden chest 4 to 8 metres in height, and of 6 to 10 square metres in superficial extent. For the preservation of the lead it is lined internally with a layer of stones, and is filled with coarse fragments of sandstone or bricks. These materials must be so selected as to resist the action of hot sulphuric acid. Whilst the hot gases from the kilns enter from beneath, they escape at the top in a cooled condition, and are conducted at once into the chambers. Sulphuric acid of sp. gr. 1·5 flows in constantly from above (either alone or simultaneously with the nitrous acid from the Gay-Lussac tower). It is distributed in the tower, comes in contact with the hot sulphurous acid, and escapes below at the sp. gr. of about 1·7. This admirable arrangement was quickly

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i "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

ii Lunge, *Dingl. Pol. Journ.*, cci, 341.

adopted in France and Germany, and has everywhere given satisfactory results. By the direct action of the hot furnace gases upon the sulphuric acid, as it occurs in Glover's tower, a powerful evaporation is effected; the sulphurous vapors arrive cooled into the chambers, where the sulphuric acid which evaporates in the tower is likewise arrested, and as the watery vapor which escapes is also conducted into the chambers, there is an economy of steam. Occasionally it has happened that the Glover's tower has been charged with a material so powerfully attacked by the hot acid that the apparatus has been totally choked up and has ceased to act. Another evil involved in the application of Glover's system consists in the fact that no satisfactory arrangements can be made to arrest the flue-dust, since the gases would be too much cooled. Thus the flue-dust is conveyed into the acid, which thus becomes contaminated with iron. For the production of common salt-cake, to be afterwards converted into soda, for the manufacture of superphosphate, etc., the acid concentrated in Glover's tower is perfectly suitable. But the process is less to be recommended for the preparation of sulphuric acid for sale, or for use in the manufacture of salt-cake for the makers of white glass.

The Glover's tower not merely effects the concentration of the chamber acid, but also the denitrification of the acid from the Gay-Lussac tower as already explained.

The further concentration of the acid from 60° to 66° B. is sometimes carried on in vessels of glass, but more commonly in those of platinum. The author has not met with any accurate statements of the outlay for glass, fuel and labor for concentrating the acid up to 1·840, but, according to communications from English manufacturers, the cost is considerably greater than for platinum vessels.[i]

Attempts have been made to render the process of evaporation in glass retorts continuous, but the results of the platinum apparatus are still more favorable. Scheurer Kestner[ii] estimates the loss of platinum at 2 grms. per ton of sulphuric acid. In a letter to A. W. Hofmann, he gives the details of the loss, and states that accurate observations have been made at Thann during three portions of time. From 1854 to 1856, when the sulphuric acid contained a small quantity of sulphurous acid, 1·92 grms. of platinum were dissolved

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i Scheurer Kestner, *Comptes Rendus*, lxxiv, 1286.

ii Scheurer Kestner, *Comptes Rendus*, lxxiv, 1286.

per ton of sulphuric acid of sp. gr. 1·840. From 1856 to 1862, the chamber acid contained nitrous acid, and 2·52 grms. of platinum were dissolved per ton of acid at 1·840. From 1862 to 1866, sulphurous acid was present, and the amount of platinum dissolved was 1·05 grms. per ton of acid of the same strength.

The chemical works at Hautmont (Department Nord) procured in 1865 a platinum apparatus holding 150 litres and weighing 28,548 grms. In 1870 the apparatus was repaired in Paris, when 7891 grms. of platinum were used, but 6275 grms. of old platinum were allowed for, and the weight of the apparatus, by the addition of 1616 grms., was increased to 30,164 grms. At the end of 1873 the apparatus weighed 28,452 grms., showing a loss of 1712 grms. During nine years' working, 6796 tons of sulphuric acid of 1·840 sp. gr. had been prepared in the apparatus. The loss of platinum was, therefore, 0·252 grm. per ton of sulphuric acid. The apparatus cost 30,588·40 francs, at 1050 francs per kilo. The repairs in 1870 cost 3439·95 francs; together, 34,028·35 francs. The worn-out apparatus was sold at 810 francs per kilo. = 23,046·12 francs. The expenditure was, therefore, 34,028·35 — 23,046·12 = 10,982·23 francs, or per 1000 kilos. sulphuric acid at sp. gr. 1·800, 1·616 francs, or about 1*s*. 3½*d*.

(To be continued.)

Amplitude of Sound-Waves.—Lord Rayleigh has communicated to the Royal Society the results of some ingenious experiments upon sound-waves. When the note was f^{iv}, with a frequency of about 2730, he estimated the amplitude at less than a ten-millionth of a centimetre. He is inclined to think that, on a still night, a sound of this pitch would be audible, with an amplitude of a hundred-millionth of a centimetre.—*Nature.* C.

Sahara.—At a late meeting of the Berlin Geographical Society, a report from Dr. von Barry was read. In his excursion into the Tuarez region of the Western Sahara, he found few grounds to sustain the theory that the desert was formerly the bed of a sea. He inclines to the belief that North Africa has long been free from a covering of water, as no traces of tertiary formations were found, and the sand downs cannot be regarded as proofs of an ancient sea. —*Nature.* C.

REMARKS ON MR. MERRIMAN'S (PH. D.) ARTICLE, ENTITLED: "AN ELEMENTARY DISCUSSION OF THE PRINCIPLE OF LEAST SQUARES."

By CHAS. H. KUMMELL, Assistant Engineer, U. S. Lake Survey, Detroit, Michigan.

The author says, in opening, that a simple and yet perfectly satisfactory proof of the main principle of Least Squares, is still a desideratum. His article being written after he had seen mine, which appeared in the *Analyst*, Vol. III, p. 133, etc., it is to be presumed that he would have improved on my representation of the subject. My paper is very abbreviated, as stated by Mr. Merriman, but is, nevertheless, clear and logical to any careful reader, and gives not a mere glimpse of the theory, but almost everything essential. Mr. Merriman's article contains a number of logical and theoretical blunders, which should not go uncorrected.

1. In the author's definitions, p. 174, I object to his restricting the problem of Least Squares to the very special case of the same quantity being measured several times. This explains the deficient enunciation of the principle of Least Squares, on p. 187, where we read: "The most probable values of quantities, measured several times with equal care, are those which render the sum of the squares of the residual errors a minimum." Here the "quantity," on p. 174, has become "quantities," but in either case "they are measured several times with equal care." This enunciation fits neither to the special case for which the arithmetic mean is the solution, nor to the general case which is solved by normal equations, for in the first case we have *one* quantity measured several times, and in the second a *function* of the unknown quantities measured in a certain stadium of that function at different times. These measured quantities are then generally different, and by far, in most cases, they cannot be measured several times. I refer, on this point, to Chauvenet's Least Squares, p. 486, also Art. 6, p. 477, because I think he handles this subject very correctly and clearly.

2. On p. 183, is given the finite equation:

$$\frac{y - y'}{x - x'} = y \, \frac{2 \, \Delta x - 2 \, x}{(m + 2) \; 2 \, \Delta x^2 \; - \; 2 \, x \, \Delta x}.$$

In passing to the limit, he obtains:

$$\text{limit}\,\frac{y - y'}{x - x'} = \frac{-2\,y\,x}{2\,(m+2)\,\Delta x^2}.$$

It seems to me that Mr. Merriman, who only says, on p. 181, that m is very great, should consider the term $2\,(m+2)\,\Delta x^2$ an infinitesimal of the second order, which ought to vanish in comparison with $2\,x\,\Delta x$. If m is infinite, as he seems to intimate when he calls $m + 2$ "indefinitely great," then the terms in question are each infinitesimals of the first order, and both should be retained; the 2 should, however, be omitted in comparison with m. Where, then, is the evidence, *in the author's line of arguments*, that his limit value is correct? It is correct, however, if the number 2 is also omitted, and the reasons proper are given in "Price's Calculus," Vol. II, p. 378, and p. 134 of my article. Price, however, commits here a different blunder, viz., by assuming that the elementary error, Δx, becomes $d\,x$ at the limit, instead of $\frac{1}{2}\,d\,x$. On this point Mr. Merriman is correct, but he was anticipated by me.

3. The author also says, on p. 183, that Δx^2 is an indefinitely small quantity of the same kind as x. This must be a misprint, although this supposition seems to be untenable, since I have before me a copy of the article, corrected by the author himself. If I read x^2 instead of x, I cannot yet see the logical connection with the statement, "the product $(m+2)\,\Delta x^2$ is hence a positive constant." The product $(m+2)\,\Delta x^2$, or rather $m\,\Delta x^2$, is, however, a constant, for the following reasons: m is an absolute constant, because the total number of element errors, $+\,\Delta x$ and $-\,\Delta x$, is entirely independent of the observations. It must be infinite, however, in order that the probabilities in the third column of the table, on p. 182, may be continuous. $\Delta x^2 = \frac{1}{4}\,d\,x^2$ is a constant for a particular class of observations, larger for poor observations than for good ones. This explains why, if we assume $h = \dfrac{1}{\Delta x\,\sqrt{m}}$, h is a measure of precision.

4. On p. 185, the author says: "The probability y' of any particular error x' depends upon the constants c and h, and will be the larger the greater those constants are; c and h are, hence, related to the precision of the observations." This is correct if c is excepted, which has nothing at all to do with the precision of the observations;

it is an absolute constant, since it is the constant of integration of the equation,

$$\frac{d\,y}{y} = -\,2\,h^2\,x\,d\,x,$$

and the only condition it has to fulfil is that

$$\sum_{-\infty}^{+\infty}\left[y\right] = \sum_{-\infty}^{+\infty}\left[c\,e^{-\,h^2\,x^2}\right] = 1.$$

I have proved in my article, p. 135, that, using Mr. Merriman's notation,

$$c = \sqrt{\frac{2}{m\,\pi}} \text{ where } m = \infty.$$

Eliminating m by means of the equation $h^2 = \frac{1}{2\,m\,\varDelta x^2} = \frac{2}{m\,d\,x^2}$, we obtain,

$$c = \frac{h\,d\,x}{\sqrt{\pi}};$$

and, consequently,

$$y = \frac{h\,d\,x}{\sqrt{\pi}}\,e^{-\,h^2\,x^2}.$$

To test this we have, as we should,

$$\sum_{-\infty}^{+\infty}\left[y\right] = \frac{h}{\sqrt{\pi}}\int_{-\infty}^{+\infty} d\,x\,e^{-\,h^2\,x^2} = 1.$$

It is important that c should be independent of the precision of the observations, for how could it be admitted that (p. 187) the compound probability of a system, viz.,

$$P = c_1\,c_2\,c_3 \ldots . e^{-(h_1^2\,x_1^2 + h_2^2\,x_2^2 + h_3^2\,x_3^2 + \ldots .)},$$

is to be a maximum, if

$$h_1^2\,x_1^2 + h_2^2\,x_2^2 + h_3^2\,x_3^2 + \ldots . = \text{a minimum},$$

as long as P is also a function of c_1, c_2, $c_3 \ldots .$, which are, according to Mr. Merriman, related to the precision of the observations. Chauvenet, who follows Gauss's reasoning in his "Theoria Motus," makes a similar hasty assumption. He has

$$P = h_1\,h_2\,h_3 \ldots \pi^{-\,\frac{1}{2}\,m}\,e^{-[h^2\,x^2]} = \text{maximum},$$

if $\quad [h^2\,x^2] = \text{minimum};$

apparently assuming that h_1, h_2, h_3 . . . are of no consequence if they appear as factors of the power of e.

5. Mr. Merriman considers Hagen's proof the best. Does he mean Hagen's own proof, or all those proofs which start with the same fundamental principle? Now this principle, as Hagen says on page 28 of his book, is due to the celebrated English physicist, Thomas Young, who published it in the Philosophical Transactions for 1819. But, although Hagen started with a correct principle, he did not prove Least Squares. Let us see!

On page 38 he arrives at the expression:

$$y = \frac{1}{\sqrt{n\pi}} e^{-\frac{x^2}{n}}.$$

On page 32 we find $n = \frac{1}{2} v = \infty$,
hence, introducing this value of n, we have

$$y = \frac{1}{\sqrt{\infty \pi}} \times 1 = 0.$$

An absurd equation like this would never be employed to prove Least Squares. Nevertheless, Hagen, ignoring this, apparently establishes the principle. The cause of this absurd result is that Hagen departs several times from the straight course of reasoning. (Compare the queer reasoning at the bottom of page 33, and the incompatible equations: $y' - y = -\frac{2x}{n} y$ and $dy = -\frac{2x}{n} y\, dx$ on page 34.)

Mr. Merriman says in a historical sketch, which appeared in the *Analyst*, March, 1877, that I had given Hagen's proof. Now who would like to be accused of such a thing? If Hagen's proof was consistent, it would have been a compliment to me, as I had never seen Hagen's proof before I wrote my article. Mr. Merriman, however, thinks Hagen's proof the best, and he says he gives Hagen's proof in his article. But to do justice to Mr. Merriman, his proof is not near so bad as Hagen's, for the reason that he follows pretty closely Price's presentation, sometimes also adopting, in a disguised form, my own. I take opportunity to state here, that for the first two pages of my article to equation (11), Price's excellent work, already mentioned, has been my only source of information. I corrected, however, an error already mentioned, and discarded the

unnecessary illustration by a curve, which, I think, has rather contributed to obscure the subject. For the remaining part I am indebted principally to Chauvenet's Least Squares, and Fischer's Geodesy. Whatever is not found in these three authors I claim as original.

Electricity of the Torpedo.—M. Marey was led, by some experiments which he made in 1871, to investigate the relations between the voluntary electric discharge of the torpedo and the voluntary muscular contractions of animals. By the aid of M. Marcel Deprez's electro-magnetic signal, which is able to register more than 600 successive electric currents per second, he found that the torpedo shock is a complex act, formed of successive currents, which follow each other at very short intervals, commonly ranging between $\frac{1}{80}$ and $\frac{1}{140}$ of a second. The effects of gradual fatigue upon the discharges, the varying intensity of the current, the correspondence between primary and induced currents, and the analogy to the series of efforts which produce ordinary muscular contraction, are all illustrated by M. Marey's diagrams.—*C. R.*, Jan. 22. C.

The Cave-Dwellers.—Dr. Mitchell, of Edinburgh, places the cave-man in the bone rather than in the stone age. His weapons were made of bone or horn, and highly finished, while his stone implements were extremely rude. The art faculty and the cranial developments of the cave people, show that they possessed a high capacity for culture.—*Nature.* C.

Objection to the Algerian Sea.—In a letter to M. Daubrée, M. Naudin states his fears that if the shallow Algerian *chotts* are filled with water, they will form an immense pestilential breeding place, worse than the Tuscan Maremma or the Pontine Marshes. The greatest depth in the centre of the basin would not exceed 25 metres, and over most of the surface the water would be very shallow. All the conditions would be favorable to an immense multiplication of organic life, decay and miasm.—*Comptes Rendus.* C.

Shaw's Gunpowder Pile-Driver.—M. Lavoinne gives a detailed account of Shaw's pile-driver, as improved by Prindle, with calculations of the work done: 1, till the moment of explosion; 2, at the instant of explosion; 3, during the ascent of the ram.—*Ann. des Ponts et Ch.* C.

THE UPWARD JETS OF NIAGARA.[1]

By W. H. Barlow, F. R. S.

When visiting Niagara last year, after acting as one of the judges at the Centennial Exhibition at Philadelphia, I observed certain physical effects connected with the Great Falls, to which I desire to draw attention.

1. It was observable that the doors and windows of our hotel, unless tightly closed, were subjected to a jarring movement, the impulses of which varied in time and degree.

The hotel in question is Clifton House, on the Canada side; its southern face being parallel to and nearly opposite the American Falls, from which it is distant about a quarter of a mile, and its south-west corner is not far from being opposite to the mean line of face of the Canada or Horse-Shoe Fall, the distance being somewhat over half a mile.

The windows of the hotel opened on hinges, and if one of them was set slightly opened, and the observer placed himself in such a position as to see the reflections of distant objects on the surface of the glass, the times and varying intensity of the jarring impulses could be clearly seen.

2. On looking at the Falls themselves, and especially at the Horse-Shoe Fall, there appeared from time to time, through the mist which always envelops the lower part of the Falls, jets of water projected suddenly upwards.

These jets frequently rose much above the level of the upper part of the fall. Judging from the known height of the Falls they frequently rose from 10 ft. to 30 ft. above the upper level. They occurred at varying intervals; but very few minutes elapsed without seeing one of greater or less magnitude. It was also observable that they had a characteristic form, somewhat resembling a pine-tree, that is to say, small or pointed at the top, and widening out downwards. They were not formed of a compact mass of water, but had that appearance, which is seen in large fountains, of being composed of lumps of water of various sizes, decreasing in the lower part, until they were lost in the general mist which surrounded the lower part of the Falls.

[1] Paper read in Section G, before the British Association at Plymouth.

The continual recurrence of these jets, and the continual recurrence of the jarring action above referred to, point to the conclusion that both effects are due to one cause, and my object in drawing attention to the subject is to endeavor to suggest the nature of the cause which is producing these effects.

Proceeding to a nearer view of the waters by going beneath the Falls, and looking at and through them, it becomes apparent that the water which flows over the upper rocks in a continuous curved stream, breaks up into masses of greater or less magnitude during its descent, so that air in large quantities gets in and between the falling masses of water. In this intermixing of air and water it may frequently happen that a quantity of air is surrounded and enclosed in a heavy mass of water, and falling in this state with a velocity due to the height of 150 ft. or 160 ft., the contained air would become suddenly and violently compressed on striking the rocks below. The energy of the charge of compressed air thus suddenly generated, would burst through the thinnest layer of its surrounding water, and so constitute a species of explosion, carrying a portion of the water with it. Assuming the weight of water which generated the compression to be greater than that on which the energy of the compressed air operated, the effect would be to project the smaller mass of water with a greater velocity than that due to the original fall. The supposition most consistent with the observed phenomena appears, therefore, to be that the two effects, namely, the jets of water and the jarring action shown on the doors and windows, are both due to the explosions or sudden expansions of air compressed by the falling water as above described. There are several circumstances which appear to favor this supposition.

1. The sudden upward blasts of air accompanied by water, felt by persons when beneath the Falls, which are probably only minor effects of a like action.

2. The jarring motion imparted to the doors and windows appears to have no corresponding effect in the solid ground; from which it may be inferred that the effect is due to concussions conveyed through the air, and not to the tremor of the earth by the weight of the falling water.

3. The characteristic form of the jets, which is similar to that produced by explosions under water, when the conditions are such as to throw the water to a considerable height.

And lastly. The suddenness and energy of the operating force as shown by the jets being frequently projected considerably above the level of the upper water.

The inquiry is one of some interest, and may serve to throw light upon those anomalous effects, which have been observed from time to time, with regard to heavy seas falling on a rocky shore, and the extreme height to which the water is occasionally projected under these conditions.

Two notable instances of this kind have been given by the engineers of the English and Scotch lighthouses.

One at the Bishop lighthouse, where a fog-bell weighing 300 cwt., and fixed at a height of 100 ft. above the sea, was displaced and thrown down to the rocks below.

The other occurred at the North Unst Lighthouse, which is built on a rock whose height is 196 ft. above high water, and presenting an almost perpendicular face to the sea. In this case, during a heavy north-west gale, a quantity of water was projected upwards sufficient to overthrow the boundary walls and force open the door of the house.

With regard to the form of jet produced by a subaqueous explosion near the surface, I had the opportunity, a short time since, of witnessing an experiment made by Professor Abel at the Royal Arsenal at Woolwich. The explosive used was compressed gun-cotton. The jet on this occasion rose to a great height, reminding one of the great Crystal Palace fountain, and it was remarkable from the complete verticality of its centre line of force and from the resemblance in its pine-tree form to the jets of Niagara.

Accuracy of French Tuning-Forks.—A. J. Ellis. having attacked the accuracy of the French diapason (*Jour. Soc. of Arts*, May 25; *Nature*, May 31), M. Koenig quotes a complimentary letter of Helmholtz to M. Appeur, in which he expresses his astonishment at the accuracy and constancy of his tonometer. He found for his Paris diapason 435·01 vibrations per second, corresponding within less than $\frac{1}{400}$ of 1 per cent. with the official standard of 435 vibrations. Koenig also refers to the corroborative results obtained by Lipajens, Desains, and Mayer, in charging Ellis with unseemly haste, in disparaging the work of a skilful mechanic who could not expect so unjustifiable an attack.—*Les Mondes.* C.

Cosmical Dust.—The attention of modern physicists has been directed to the particles of dust which are at all times floating in the air. Many of them come from the soil, but some are characterized by a special chemical composition and form, which show that they have reached us from the interplanetary spaces. In 1825, Brandes examined, during a number of successive months, the chemical substances contained in the rain water, near Salzüflen, in Germany. He found various organic and mineral substances, among which oxide of iron was especially noteworthy. In 1851, M. Barral, in a series of analyses of the rain water collected at the Paris observatory, distilled 5·57 litres of water, which gave him a dry, yellowish residuum, weighing 183 milligrammes, a portion of which was insoluble in water, alcohol or ether. Its solution in *aqua regia* gave all the reactions of iron. The idea of attributing these minute particles of iron to a fall of cosmic dust seems first to have occurred to Ehrenberg. After analyzing numerous specimens of dust, which had fallen upon vessels at Malta and in the Indian Ocean, he at first supposed that they were of African origin; but noticing their difference from any of the African sands in color, the great geographical distances which they must have traveled according to his first hypothesis, and the amount of oxide of iron which they contained, he broached the theory that they had fallen from the upper layers of the atmosphere.

This hypothesis was adopted and extended by M. Nordenskjöld. In a letter to M. Daubrée, Sept. 9, 1872, he mentions finding, in a careful analysis of snow, soot-like particles, containing organic matter and minute pellets of metallic iron. Thinking that this dust might possibly have come from the chimneys of Stockholm, he requested his brother, who lived in a remote part of Finland, to collect and send him some snow, in which he found particles of the same description. In 1873 and 1874 he repeated his observations at Spitzbergen, and on the glacier of Inlandis, in the interior of Greenland, finding magnetic iron, oxide of iron, nickel and cobalt, which satisfied him of "the existence of a cosmical dust, falling imperceptibly and continually."

In 1875 and 1876 Gaston Tissandier and E. Young, independently collected dust from the towers of cathedrals and other elevated places, which they subjected to chemical and microscopic examinations. By means of a magnet they discovered small spherical corpuscles with a slight roughness, which made many of them somewhat bottle-shaped,

resembling, in appearance, iron which has been reduced to an impalpable powder, and burnt in a hydrogen flame. Young also collected snow at Montreux, Les Avants, Hospice of St. Bernard, and Chanossal, being careful to avoid the lower layers, which might have absorbed something from the soil, and the upper layers, which might have been stained by vegetable débris. The residues from the evaporation of the several samples were first dissolved in distilled water, which separated the chlorides, then in pure chlorhydric acid which showed no trace of iron. Chemical reagents showed the presence of iron in each of the residues, and there were often irregular particles which were attracted by the magnet. He found none of the characteristic globules, but M. Tissandier found them in the sediment of some snow which his brother collected on the side of Mont Blanc, at the Col-des-Fours, at a height of 2710 metres.

M. Young proposes to continue his observations on a larger scale. He feels justified already in affirming that the interplanetary spaces are not destitute of solid materials, but they contain very minute metallic particles; that those particles, when drawn into our atmosphere, play an important part in the dispersion of light, as Tyndall has shown by his experiments; that they help to explain the luminous trains of bolides and the peculiar spectra of auroræ-boreales, and that these microscopic aerolites, by their daily arrival, must increase the earth's mass, so as to afford an explanation, as M. Ch. Dufour has shown, of the moon's secular acceleration. He closes his paper with the following conclusions:

1. That iron exists in all the dust which has been accumulated, in church towers, by the winds of ages.

2. That this iron, floating in the atmosphere, is trapped in its fall by the snow, in which it is always found.

3. That its globular form indicates that it has been raised to a high temperature.

4. That facts tend to prove its celestial origin.

5. That it plays an important part in the physics of the globe, but that science, in order to fully understand it, should seek to estimate the phenomenon quantitatively, and to study it in its variations.—*Bulletin de la Société Vaudoise*, No. 77. C.

MANNER OF LAUNCHING THE STEAMSHIPS PEKING AND TOKIO.

The steamships *Peking* and *Tokio* were built for the Pacific Mail Steamship Co., by Messrs. John Roach & Son, of New York, and Chester, Pa., and run between San Francisco, U. S., and Yokohama, China. They are iron steamers and were built at the Delaware River Iron Shipbuilding and Engine Works, Chester, Pa., and launched March 18th, 1874.

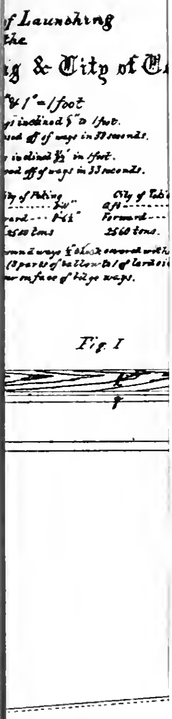
They are 419 feet over all, $396\frac{1}{2}$ feet on 18 foot water line, $47\frac{1}{3}$ feet beam, and 38 feet 5 inches deep from base line to spar deck at centre, and register $5079\frac{25}{100}$ tons.

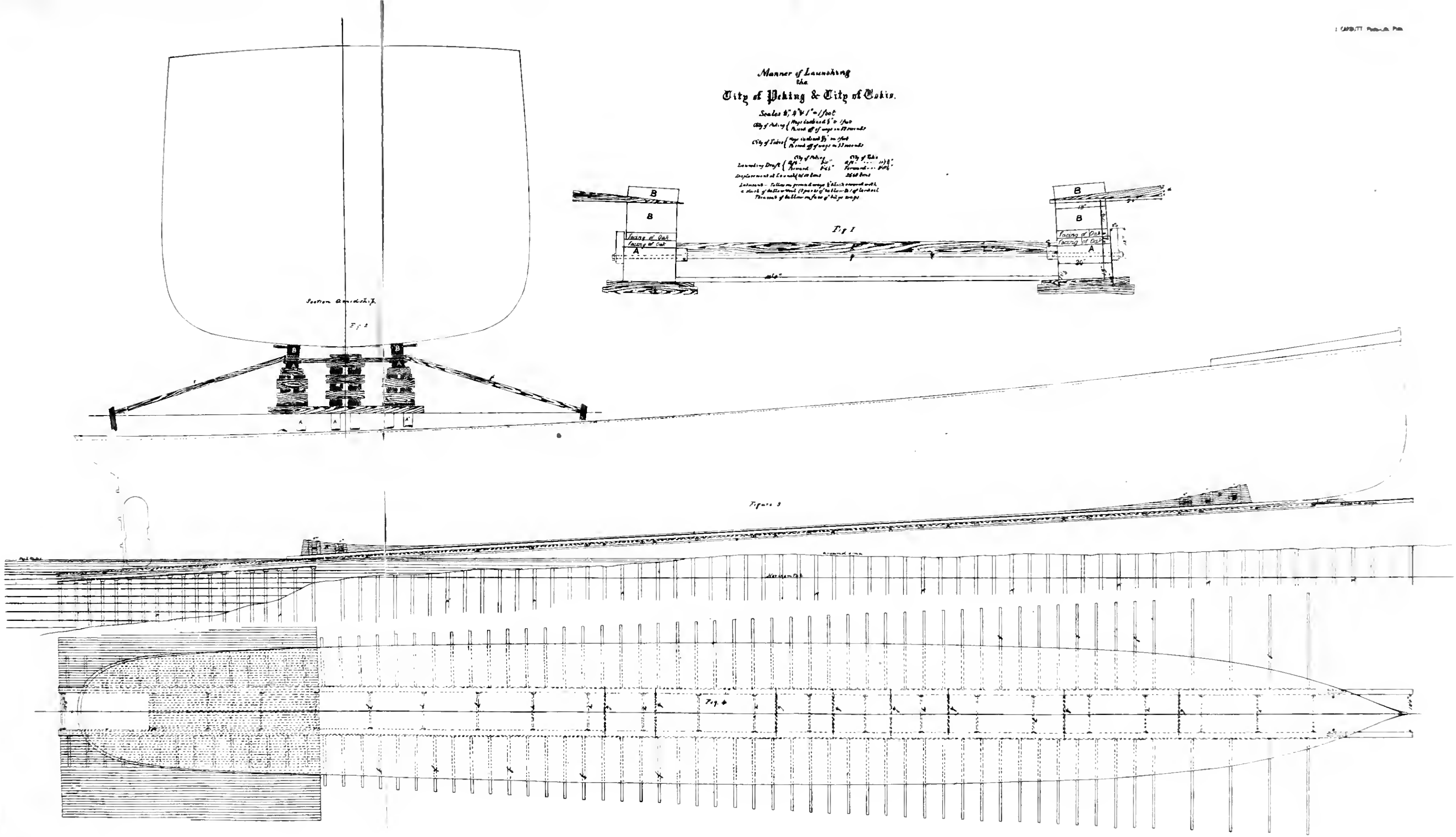
The accompanying plate illustrates the method of launching these steamers, which was very successful.

A, Figs. 1 and 2, represents the "ground ways," which rest on the blocking placed on cap piece of piles A', Figs. 2 and 3, and are 430 feet each, fastened together with bolts, and faced with oak $2\frac{3}{4}$ inches thick. B represents the "Bilge ways," upon which the ship rests after the shores and bilge blocks have been knocked away, and are 325 feet long, fastened together by ropes passing through holes in ends.

B', Figs. 1 and 3, is the "packing," extending 300 feet from end to end; at the "ends" the "packing" is held tightly to plating by chains passing through it and under the keel, as shown at c, c', c'', c''', c'''', Fig. 3. The wedges d, Fig. 1, are placed every 2 feet apart, and are used for setting up the packing immediately before knocking away shores and blocking, a few moments preceding launching. The bilge ways are fastened to ground ways at e, Figs. 3 and 4, by a piece of oak, 3 inches thick, which, when all is ready, is sawed in two, and the ship moves down the ways. The ways are kept from spreading by struts f, f, f, Figs. 2 and 4, and tied together by tie-rods g, Figs. 1 and 4, and held apart by distance pieces h, Figs. 1 and 4. The ways under the steamship *Peking* were inclined $\frac{5}{8}$ inch in 1 foot to the horizontal, and the ground ways covered with tallow $\frac{1}{2}$ inch thick, over which was laid a slush of tallow and oil (3 parts of tallow to 1 of lard oil). The bilge ways were covered with a thin coat of tallow. The *Peking* passed off the ways at this angle in 38 seconds.

Under the *Tokio* the ways were inclined $\frac{21}{32}$ inch in 1 foot to the horizontal, and the same lubricant used. At this angle, the ship passed off the ways in 33 seconds. The steamers, at the time of launching, weighed 2560 tons each. J. E. W.


f Launching
the
g & City of
Fig. I



Manner of Launching
the
City of Peking & City of Tokio.
Lubricant –
Fig 1
B
B
Facing of Oak
Facing of Oak
A
Section Amidship
Fig 2
B
B
A
A
Figure 3
Horizontal
Fig. 4

PLANETARY MECHANICS.

By Pliny Earle Chase, LL. D.

From the earliest days of philosophy, the natural tendency of the human mind towards unity has awakened a desire to resolve all forms of activity into modifications of a single ultimate force. After Franklin's identification of lightning and electricity, there was a general disposition to regard electricity as the primal energy. The investigations of Rumford, Mayer, Joule, Colding, and their collaborators, led to the establishment of the modern science of thermo-dynamics, and a consequent proneness to enthrone heat, in the place of electricity, as the highest "mode of motion."

The Smithsonian Report, for 1876, contains an interesting and important paper, by William B. Taylor, on "Kinetic Theories of Gravitation." His valuable summary of the various attempts which have been made "to discover an origin or antecedent of gravitation," begins with the endeavor of Dr. Robert Hooke, in 1671, "to trace the cause of gravitative fall to the external action of waves in a surrounding medium." Newton's hypothesis of an æther, as the source of "the electric and magnetic effluvia and the gravitating principle," was propounded in 1676; and, in 1693, he wrote to Dr. Bentley: "Gravity must be caused by an agent acting constantly according to certain laws; but whether this agent be material or immaterial, I have left to the consideration of my readers." Villemot in 1707, John Bernouilli in 1734, Lesage in 1750, Euler in 1760, Young in 1807, Herapath in 1816, Jules Guyot in 1832, Faraday in 1844, Seguin in 1848, Boucheporn in 1849, Lamé in 1852, Waterston in 1858, Challis in 1859, Glennie in 1861, the Kellers in 1863, Tait in 1864, Saigey in 1866, Croll in 1867, Leray in 1869, Boisbaudran in 1869, Guthrie in 1870, Crookes in 1873, are all quoted, in order to show the principal forms of the hypothesis that gravity is due to external impulsion, and the prominent defects of such a hypothesis are clearly pointed out.

There is one great objection to all unitary physical theories, in the very nature of mind. We think only under relations, and all relations require at least two correlates. Newton's third law expresses the physical consequence of such necessary correlation, by saying

that "action and reaction are always equal, and in opposite directions." Laplace concluded[i] that the velocity of gravity is at least 100,000,000 times as great as the velocity of light, and that, therefore, "mathematicians may continue to regard it as infinite." This conclusion implies a necessary dualism, by showing the co-existence of instantaneous and progressive activities, and the consequent necessity for an immaterial, as well as for a material, medium. For, if inertia is a necessary quality of matter—time being required to overcome inertia—an instantaneous physical transmission of force is at variance with fundamental physical laws, and utterly inexplicable on physical grounds.

Gravitation, whatever may be its origin, is a centripetal action or reaction. What is its equal and opposite reaction or action? It should obviously be centrifugal, linear, radial and constant. The only form of such activity, of which we have any evidence, is found in the solar radiations which give us light, heat and actinism; which affect terrestrial electricity and magnetism; and which, as Sir John Herschel says, "are the ultimate source of almost every motion which takes place on the surface of the earth." At first glance, it may seem strange to try to make any comparison between light and gravity, but the following extract from Tyndall's lectures shows that radiating energy is fully as important as absorbing energy:

"Look at the integrated energies of our world—the stored power of our coal fields; our winds and rivers; our fleets, armies and guns. What are they? They are all generated by a portion of the sun's energy, which does not amount to $\frac{1}{2300000000}$ of the whole. This is the entire fraction of the sun's force intercepted by the earth, and we convert but a small fraction of this fraction into mechanical energy. Multiplying all our powers by millions of millions, we do not reach the sun's expenditure. And still, notwithstanding this enormous drain, in the lapse of human history we are unable to detect a diminution of his store."[ii]

The centrifugal activities are generally supposed to be propagated through an indefinitely, but extremely, elastic medium, called the æther. Many investigators, however, think that there is no necessity for imagining such a medium, and it may be granted that we have no positive evidence of its existence. But the modes and results of transmission are such *as if* there were such a medium, and the scien-

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i *Mécanique Céleste,* X, vii, 22, *g.*

ii "Heat as a Mode of Motion." N. Y. ed., 1873, p. 466.

tific accuracy of conclusions will not be vitiated by any reasoning which introduces the laws of elasticity for purposes of illustration, or for facilitating deductions.

In the September number of this JOURNAL it was shown that the principal lines of the solar spectrum, and the distances of planets from the sun, are arranged in accordance with harmonic laws. It was further shown that the masses of the principal planets involve a figurate series, which is also found in the arrangement of the Fraunhofer lines. Such results are simple and familiar consequences of well-known laws, which govern synchronous vibrations in elastic media. In following up their indications, for the purpose of seeing if we can find the equality of action and reaction, we may reasonably suppose that the Sun and Jupiter, which are the two governing masses of our system, should exhibit marked evidences of their controlling influence. If we compare them at Jupiter's perihelion, we find that the product of Jupiter's radius-vector by its mass is 1·0153 times the product of Sun's radius by its mass. If we take $n = 1{\cdot}0153$, and $a = 6 \times {\cdot}0153 = {\cdot}0918$, the harmonic progression $\frac{1}{n+a}$, $\frac{1}{n+2a}$, $\frac{1}{n+3a}$, etc., gives us the following nodal and internodal divisors:

	Nodal.	Internodal.		Nodal.	Internodal.
1	1·0000		$n + 6\,a$	1·5661	
		1·0536			1·6350
$n + a$	1·1071		$n + 7\,a$	1·6579	
		1·1530	$n + 8\,a$	1·7497	1·7497
$n + 2\,a$	1·1989		$n + 9\,a$	1·8415	
		1·2448			1·8644
$n + 3\,a$	1·2907		$n + 10\,a$	1·9333	
		1·3366			1·9792
$n + 4\,a$	1·3825		$n + 11\,a$	2·0251	
		1·4284			2·0939
$n + 5\,a$	1·4743		$n + 12\,a$	2·1169	
		1·5202	$n + 13\,a$	2·2087	2·2087

It will be observed that the first six internodal divisors are arithmetical means between the adjacent nodal divisors, and that the others are formed by successive denominator increments of $\frac{5}{4}\,a$.

In a condensing nebula we may naturally look for such relations between density and distance as prevail in elastic media. One of the most important of those relations is involved in all barometric measurements of altitude. When the distance from the seat of maximum pressure varies arithmetically, the density varies either geometrically

or harmonically: geometrically if the central force is constant, harmonically if it varies inversely as the square of the distance.

If we take the wave-length of the Fraunhofer line $A = 761{\cdot}20$, as the common numerator of our linear nodal harmonics, and Neptune's mean distance = 6453 solar radii as the common numerator of our exponential internodal harmonics, we find striking accordances between this theoretical order and the actual order of nature, as shown in the centrifugal interferences of luminous waves, and in the centripetal interferences of nebular condensation. These accordances are grouped in the following table. The "quotients" are obtained by dividing 761·20 by the nodal divisors; the "roots," by extracting such roots of 6453 as are indicated by the internodal exponential denominators:

Denominators.	Quotients.	Observed.	Roots.	Observed.	
1	761·20	*A* 761·20	6453	6453	Neptune.
			4130	4122	Uranus.
$n + a$	687·56	*B* 687·49			
		C 656·67 [i]	2015	2050	Saturn.
	634·92				
			1150	1118	Jupiter.
$n + 3a$	589·76	*D* 589·74			
			708	728	Freia.
	550·60		[570	574	Juno].
		E 527·38 [i]	465	473	Flora.
	516·31	*b* 517·70			
			321	327	Mars.
$n + 6a$	486·05	*F* 486·52			
			214	215	Earth.
	459·13				
	435·05	*G* 431·03 [i]	150	155	Venus.
	413·37				
		H 397·16 [i]	111	110	Ven.-Mer.
$n + 10a$	393·73	*H′* 393·59			
			84	83	Mercury.
	375·88				
			66	64	Mercury, s. p.
	359 58				
	344·64		53	53	Mercury, c. o.

[i] *C*, *E*, *G* and *H*, seem to indicate special planetary reactions. The denominators are: *C* 1·1590, Saturn's mean perihelion 1·1576; *E* 1·4434, Earth's major-axis 1·4468; *G* 1·7660, Venus's secular perihelion 1·7640; *H* 1·9166, Mercury's mean aphelion 1·9139. The average deviation of all the lettered lines, from their theoretical values, is less than $\frac{1}{8}$ of 1 per cent.; the maximum deviation is only ·27 of 1 per cent.

The alternate Fraunhofer lines, *B, D, F, H′*, indicate the most striking harmonies, since they are not only nodal, but also figurately nodal. The intermediate lines show the influence of simple secondary harmonies, in addition to their planetary analogies, as may be seen by the following internodal and observed denominators:

$n + a + \frac{a}{2}$	1·1530	*C* 1·1590
$n + 4a + \frac{2a}{3}$	1·4437	*E* 1·4434
$n + 5a$	1·4743	*b* 1·4702
$n + 8a + \frac{a}{6}$	1·7650	*G* 1·7660
$n + 10a - \frac{a}{6}$	1·9180	*H* 1·9166

The observed internodal positions represent mean planetary distances, until we pass the orbit of Venus. "Ven.-Mer." is the arithmetical mean between Venus's mean distance (155) and Mercury's secular perihelion (64). "Mercury c. o." is the centre of spherical oscillation of a nebula extending to Mercury's mean distance.

It is evident, therefore, that there is a similarity of law governing the centrifugal and centripetal phenomena. It remains to be seen whether we can find a similarity of energy.

Any constant velocity which is due to the action of a central force varying as $\frac{1}{h^2}$, whether the force be centrifugal or centripetal, may be represented by $\sqrt{fh}$; any wave- or dissociating-velocity, by $\sqrt{2fh}$. If the latter velocity is diminished in any degree by the interposition and resistance of inert material particles or bodies, there will be an immediate tendency to central aggregation. The motion which is imparted in the aggregating process must all be efficient, either in rotation, in maintaining molecular orbits, in overcoming inertia, or in some other form of internal or external activity. The limit towards which all the internal and external energies tend, should be the limit which marks the equality of action and reaction for which we are looking.

Whatever may be the internal cyclical variations of velocity in any system, the tendency of the system to association or dissociation with

any other system will be determined by the average velocity. Radial oscillations through twice the major-axis, are synchronous with circular or elliptic oscillations about the same major-axis. The average radial velocity is, therefore, $\frac{2}{\pi}$ of the synchronous average circular velocity, or $\frac{\sqrt{2}}{\pi}$ of the average dissociating velocity. The velocity of planetary revolution, v_1, varies as $\sqrt{\frac{1}{h}}$; the velocity of rotation, v_2, in a contracting or expanding nucleus, as $\frac{1}{h}$. The average internal centrifugal velocity within the sun's mass, $\frac{2}{\pi} v_2$, and the average dissociative centripetal velocity, $\sqrt{2}\, v_1$, would be equalized when $h_2 = \left(\frac{2}{\pi} v_2 \div \sqrt{2}\, v_1\right)^2 h_1$. If h_1 represents the present solar radius; v_1 the present limiting velocity of possible free revolution (revolution at sun's surface); v_2 the present limiting or maximum velocity of rotation (at same point); the limiting velocity of equal centrifugal and centripetal action and reaction is *the velocity of light.*

If the theory of Boscovich were true, or if all the inertia of the solar mass could be removed, or if the limit of centrifugal and centripetal equality could be in any other way attained, the following average velocities would then all be equalized:

1. The æthereal wave velocity.
2. The solar dissociative velocity.
3. The velocity acquired by infinite fall to sun's surface.
4. The average internal centrifugal velocity.
5. The velocity acquired by actual fall through half-radius.
6. The velocity acquired by virtual fall through radius.
7. The velocity acquired by virtual centrifugal action through radius.
8. The uniform velocity which would give the same amount of radial displacement as the varying radial centrifugal velocity.
9. The uniform velocity which would give the same amount of tangential displacement as the superficial dissociating velocity.
10. The velocity of light.

Weber, Kohlrausch and Maxwell have shown that the electrostatic and electromagnetic forces may also be connected by means of the velocity of light. Maxwell, consequently, regards light as a variety of electromagnetic action. Its velocity is the greatest of which we have any positive knowledge, and there are good reasons for believing that it is the greatest possible velocity of strictly physical propagation. It is true that Wheatstone's famous experiments with a rotating mirror, showed an apparent velocity, for electricity, of 288,000 miles per second. But his experiments have never been repeated, and there must have been electrical induction between proximate coils of the conducting wire, which may very likely have been overlooked, and may, therefore, have vitiated his results. The instantaneous velocity of action, which Laplace supposed to attend gravitation, cannot be regarded as a physical or material velocity, in any sense which can be reconciled with commonly accepted definitions of physics and matter.

We thus find in light, heat, actinism, electricity, electromagnetism, gravitation, association and dissociation, evidences of central force propagated with the velocity of light. Centrifugal action seems predominant in some of these different forms or phases of energy, and centripetal action in others. But there is an undoubted dualism pervading them all, and producing cyclical orbital oscillations, to which, perhaps more than to anything else, they owe the distinctive manifestations which lead us to give them distinctive names. There may always be good reasons, on strictly philosophical grounds, for objecting to the appropriation of either of those names, as a technical designation for the primitive force. But the importance of the eyes as educators, the universal diffusion of light, the relations between light and terrestrial energies, and the fact that the velocity of light is the main evidence of a common pervading energy, justify the use, in popular language, of the term which is applied to solar radiation, when we wish to speak of the common energy. The additional consideration of the immaterial element, in instantaneous gravitating action, lends new significance to the words of the SEER: "And the Spirit of God moved upon the face of the waters. And God said Let there be light: and there was light."

HAVERFORD COLLEGE, *Sept.* 10*th*, 1877.

ELEMENTARY SPECTRAL HARMONIES.

In the wave-lengths of the principal spectral lines of gold, if we take the largest wave-length for our common numerator, and make $a = \cdot 0256$, we find the following harmonic accordances in the denominators:

Wave-Lengths.	Actual.	Theoretical.	
628·23	1·0000	1·0000	1
596·57	1·0531	1·0512	$1 + 2a$
595·08	1·0557	?	?
583·95	1·0758	1·0768	$1 + 3a$
523·46	1·2001	1·2048	$1 + 8a$
479·76	1·3095	1·3095	$1 + 12a$

The second set of denominator-increments ($8a$, $12a$), is four times the first set ($2a$, $3a$).

Barium presents the following harmonic groups:

Wave-Lengths.	Actual.	Theoretical.	
650·24	1·0000	1·0000	1
614·78	1·0577	1·0578	$1 + 2a$
597·05	1·0891	1·0867	$1 + 3a$
582·88	1·1156	1·1156	$1 + 4a$
553·96	1·1738	1·1734	$1 + 6a$
493·78	1·3168	1·3179	$1 + 11a$
453·46	1·4340	1·4335	$1 + 15a$
611·75	1·0629	1·0625	$1 + b$
578·41	1·1240	1·1250	$1 + 2b$
493·78	1·3168	1·3125	$1 + 5b$
453·46	1·4340	1·4375	$1 + 7b$
609·17	1·0674	1·0654	$1 + 6c$
603·08	1·0782	1·0763	$1 + 7c$
585·51	1·1106	1·1090	$1 + 10c$
553·96	1·1771	1·1744	$1 + 16c$
542·87	1·1978	1·1962	$1 + 18c$
490·20	1·3265	1·3270	$1 + 30c$
456·36	1·4248	1·4242	$1 + 39c$

HAVERFORD COLLEGE, *Sept.* 22*d*, 1877. P. E. C.

New System of Electro-Magnets.—M. Cauce substitutes small rods of soft iron for Camacho's tubular nuclei, with the following claimed advantages: 1, there is very little residuary magnetism; 2, the sphere of lateral attraction may be largely increased; 3, the construction is remarkably simple.—*Comptes Rendus.* C.

JOURNAL

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FOR THE

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VOL. CIV. NOVEMBER, 1877. No. 5.

Franklin Institute.

HALL OF THE INSTITUTE, Oct. 17th, 1877.

The stated meeting was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present 170 members and 44 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the Library:

Specifications and Drawings of patents. U. S. Patent Office. For March and April, 1877. From U. S. Patent Office.

First and fifth to eighth annual reports of the State Board of Health of Massachusetts. From the Secretary of Board.

Seventh report of the South Pass of the Mississippi River. July 24, 1877. By M. R. Brown.

Map of Turkey and parts adjacent. From Secretary of War.

Minutes of proceedings of the Institution of Civil Engineers. London. Vol. 49. Sess. 1876-77. Pt. 3. From the Institution.

American ephemeris and nautical almanac, for the year 1880. From Navy Dep't.

Report of trial of steam machinery, of U. S. Revenue steamer "Gallatin." January, 1874-75. From C. E. Emery, N. Y.

Resultant fault in conduction, etc., etc., tests. By Ayrton & Perry.

Certain modifications that must be introduced in the mathematical theory of electricity.

On a neglected principle that may be employed in earthquake measurements. From Perry & Ayrton, authors, professors Imp. College of Eng., Tokio, Japan.

Report of the director of New York Meteorological Observatory, for 1876. From D. Draper, Director.

Tramways et chemins de fer sur Routes. Par P. Challot. Paris, 1877. From the Minister of Public Works, France, through Vice-Consul D'Elpeux, Philada.

Massachusetts Institute of Technology. President's report for the year 1876. Boston, 1877. From the President.

La Vue du Monde. Par F. W. C. Trafford. Lausanne, 1877. From the Author.

Treatise on the use of Belting for the transmission of power. By J. H. Cooper. Philada., 1877. From the Author.

57th report of the Managers of the Apprentices' Library Co. of Philada. 1877. From the Company.

Verhandlungen des Naturhistorisch-Medicinischen Verein zu Heidelberg. N. S. Vol. 2, Part I. Heidelberg, 1877. From the Union.

Fifty-eighth Report of the Board of Education, Philadelphia, 1877.

One Hundredth Anniversary of the Declaration of Independence. From E. Hiltebrand.

Report du directeur de l'observatoire cantonal de Neuchâtel au departément de l'interieur sur le concours des chronomêtres pendant l'année 1875. Neuchâtel, 1876.

Report of the Object, Foundation, Organization and Attendance of the Voluntary School, in St. Gall, for the improvement of merchants' and artisans' apprentices. From S. L. Smedley.

Mr. Chas. M. Dupuy, C. E., read a paper on making wrought iron direct from the ore.

The Secretary presented his report, which embraced the methods of Palamade Guzzi and of J. B. Knight, for determining the amount

of water mechanically suspended in steam;[i] C. Tyson's steam motor for sewing machines; Holman's life slide for the microscope;[ii] Hector Orr's method of printing illustrations on the Bullock press; a new and cheap form of monkey wrench, made by Morris, Tasker & Co.; E. F. Moody's pneumatic trough for lecture purposes; Diston's post-hole digger; samples of asbestos packing, steam-pipe covering, etc., made by the Asbestos Packing Company of New York; mineral wool, made from furnace slag, prepared by Mr. Elber; specimens of iron and deposits from a singular case of boiler corrosion; Brush's electric lamp, and electro-plated carbons for same; the Jablochkoff electric candle; and taps and dies for screw threads, of the Franklin Institute standard, and ring and plug gauges of the Whitworth standard, made by the Pratt & Whitney Co., of Hartford, Conn.

Mr. J. B. Knight, representative of the Franklin Institute in the Pennsylvania Museum and School of Industrial Art, reported that "The arrangement of the Collections in Memorial Hall, as referred to in my report of June 20th last, is completed, and the trustees are now desirous of supplementing their usefulness by putting in operation classes in which will be taught the principles of design, together with technical instruction in some special industries.

"To these classes, it is proposed to admit citizens of the state, at a nominal charge.

"The money provided by the original subscribers has been used in purchasing and arranging the collection, and the trustees confidently appeal to the citizens of the City and the State for the necessary means for beginning this important work, believing that if this plan of art education can now be put in operation, the Legislature of the State will soon recognize the importance of the work, and appropriate an amount of money for its permanent maintenance.

"The importance of such instruction, and especially its bearing on the great work in which the Institute has been engaged for so many years, must be apparent to you all; and for this reason these schools are commended to such material aid as will insure their opening at an early day."

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

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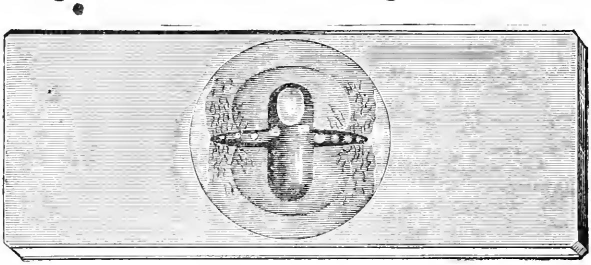
[i] See page 358, current number.

[ii] See page 292, current number.

HOLMAN'S LIFE SLIDE FOR THE MICROSCOPE.[1]

In the use of the microscope in that branch of science called biology, it is often desirable to keep under view small organisms, such as bacteria and vibriones, for hours, and even for days and weeks at a time. Hitherto this has not been possible, for lack of a proper contrivance; the animals would soon die from the exhaustion of oxygen in the confined space, and they were not in that normal condition necessary for satisfactory study during the time that they did live.

Below is pictured what is known as Holman's Life Slide, which obviates this difficulty. The construction of this accessory to the miscroscope may be described as follows: In the centre of one face of a strip of glass 3 inches long, $1\frac{1}{16}$ inches wide, and $\frac{3}{16}$ of an inch thick, are ground two very shallow cavities, side by side, oval in form, and with their length in the direction of the length of the slide; a straight



shallow groove extends between, and a little beyond, them at each end; through the centre of these cavities, and at right angles to their long diameter, but not so long as to reach their sides, a cavity is ground as deep as the thickness of the glass will permit.

The cavities and groove thus described, occupy a circular surface of the slide about $\frac{3}{4}$ of an inch in diameter, which is covered, when in use, with a circular piece of microscopic glass 1 inch in diameter.

The philosophy of its action may be thus described: Into the deep cavity, as a reservoir, is put the material in which are the organisms to be examined; the cover is then put on, and the fluid on the surface of the plate wiped away. The pressure of the atmosphere holds the thin cover firmly to the plate, and the fluid between the cover and the plate commences to evaporate at the edges, its place being supplied by more fluid from the reservoir. As the evaporation pro-

[1] Presented at the meeting of the Franklin Institute, October 17th, 1877.

ceeds, the cover is bent downwards by the atmospheric pressure, and meets a resistance at the junction of the groove with the edge of the shallow cavities, resulting in the edges of the cover rising at each end of the long groove, and a small bubble of air finds its way through the groove to the reservoir. This automatic action thus furnishes a continual supply of fresh air, and the life of the little animals is sustained during the time necessary to observe the changes that take place in them during their life history. When the smaller forms are inclosed in one of these life slides, to get access to the air they seek the edges of the cover, and range themselves in a zone, at a short distance from its rim, close to where the air comes in contact with the water. Being thus situated, in accordance with the law that compels them to take up these positions, they can be viewed with the highest powers of the microscope, and their true nature and habits much better studied than by the old methods.

In 1872, this slide was first described in this JOURNAL; and is now presented in a much improved form. D. S. H.

LECTURES AT THE FRANKLIN INSTITUTE.

The lectures for the season of 1877–8, are divided into two classes. Those in the illustrated series, to be given on Tuesday evenings, are as follows:

Seven lectures by Prof. E. J. Houston, on the Resemblances and Contrasts of Sound and Light, beginning Nov. 6th, 1877.

Six lectures by Prof. Elihu Thomson, on the Correlation of Forces, beginning Jan. 8th, 1878.

Three lectures by Prof. Pliny E. Chase, on the Manufacture of Bricks, Paper and Ink, beginning Feb. 21st, 1878.

Those in the Elementary Series, to be given on Thursday evenings, will be:

Eight lectures by Prof. E. H. Bartley, on Chemistry, beginning Nov. 8th, 1877. And

Eight lectures by Prof. E. J. Houston, on Elementary Physics, beginning Jan. 10th, 1878.

Prof. E. J. Houston has again kindly volunteered a Christmas lecture for "Young Folks," which will be given Dec. 28th.

PROGRESS OF OCEAN STEAM NAVIGATION.

The first steamer built to cross the Atlantic, carrying passengers and freight, was the Great Western, a wooden paddle-wheel steamer, built by Patterson, of Bristol, England, in 1837, and of the following dimensions:

	Feet.	Inches.
Length between perpendiculars,	212	
Beam,	35	4
Depth,	23	2

Tonnage, 1340 (builder's measurement).

Engines by Maudslay, Sons & Field, of London.

Horse Power (nominal),	420.
Type of Engine,	Side Lever.
Diameter of Cylinders,	74 in.
Stroke,	7 ft.
Paddle-Wheels (diameter),	28 "
28 Common Floats,	1 ft. 10 in. wide.
No. of Revolutions per minute,	from 10 to 18.
Steam Pressure per square inch,	5 lbs.
Average time between N. Y. and Liverpool,	15 days.

The steamers of the White Star Line, running between New York and Liverpool, have made the best time; and of the whole line, the Britannic is the fastest vessel. She is of iron, and was built by Harlan & Wolf, of Belfast, Ireland, and her engines by Maudslay, Sons & Field, of London. Her dimensions are as follows:

	Feet.	Inches.
Length between perpendiculars,	455	
Beam,	45	2
Depth,	33	7

Tonnage, 5004 (gross registered).

Compound Engines, having

2 Cylinders of 48 inches diameter, and
2 " " 83 " "

Stroke,	5 ft.
Horse Power (indicated),	4900.
Diameter of Propeller,	23 ft. 6 in.
Pitch,	31 " 6 "
Surface in square feet,	128 ft.

Average of 11 voyages,	revolutions per minute,	$52\frac{3}{10}$.
"	Pressure of Steam in Boilers, .	. 65 lbs.
"	Speed per hour, . . .	15·045 knots.
"	Coal per 24 hours, . .	101·932 tons.
"	Mean Draught of Water, .	. 23 ft. 7 in.
"	time bet. N.Y. and Queenstown,	7 days, $21\frac{8}{10}$.
To which add 18 hrs. to Liverpool,	making	8 " $15\frac{8}{10}$.

The changes that have taken place in 40 years, may be stated as follows: Iron substituted for wood, propeller substituted for paddle-wheel. Proportion of length to beam increased from 6 to 1 in the Great Western, to 10 to 1 in the Britannic. Speed increased from 8 to 15 knots per hour; time of passage decreased from 15 to 9 days.—*Engineering*, September 14th, 1877.

The Jablochkoff Light.—M. Guyot reports some recent successful experiments on the divisibility of the electric light. All parts of the workshops, where the experiments were tried, were brilliantly lighted by six chandeliers, producing altogether a light equivalent to 500 Carcel burners, softened by opaline globes. M. Denayrouze, after explaining all the advantages of employing the electric candles, distributed over seven chandeliers the light produced by the currents of two Alliance machines. Although the brilliancy was intense, it did not fatigue the eyes, on account of its perfect regulation. Messrs. Denayrouze and Jablochkoff think the Alliance machines the best for their system, on account both of their regularity and their constancy. The motive force of an Alliance machine, with six discs, is less than three horse-power, and a small machine, with two discs, is sufficient for three chandeliers. Jablochkoff's electric candles burn for two or three hours without interruption, and each chandelier holds a number of candles. The lighting is automatic; a small bit of graphite is placed across the extremity of the two carbons, against which it is held by a piece of asbestos paper; the current traverses this conductor, volatilizes it, and instantly kindles the flame. By a similar arrangement, as soon as one candle is used, the next is lighted, without any interruption.—*Les Mondes.* C.

Railroad Ties.—At a late meeting, in Constance, of the directors of German railroads, the following information was furnished by the officers of the railway from Hanover and Cologne to Minden. The proportion of pine ties, injected with zinc, renewed after 21 years,

was 21 per cent.; beech ties, injected with creasote, renewed after 22 years, 46 per cent.; oak ties, not injected, after 17 years, 49 per cent.; oak ties, injected with chloride of zinc, after 17 years, 20·7 per cent. The ties which were not renewed, appeared perfectly sound. Since 1870, the Emperor-Ferdinand-Northern Railway has used only oak ties, injected with either creasote or with chloride of zinc.—*Ann des Ponts et Chaussées.* C.

Zoicity.—M. Ziegler reports the following experiments in support of his theory of zoicity, or the necessity of animal contact to irritate the cilia of flesh-eating plants. Prepare with white wax, three kinds of granules; in the first, put pure urea; in the second, fine iron filings; and in the third, both urea and iron. Wash the granules in distilled water, dry them thoroughly in the air, and hold them for some minutes in the fingers, which should be clean and pretty dry. Then place the granules on separate leaves of healthy Drosera, and those which contain pure urea or pure iron will produce no ciliary contraction, while those which enclose the mixture cause a powerful contraction; but even the mixture, if it has had no previous animal contact, is wholly inactive.—*Comptes Rendus.* C.

Condensed Sulphide of Carbon.—By adding to 70 parts of sulphide of carbon, 20 parts of linseed oil and 10 parts of chloride of sodium, M. Mercier has succeeded in forming a solid compound. It is thought that the product may prove valuable as a remedy for the phylloxera. If placed near vines, it would probably gradually decompose, disengaging enough poisonous vapor to kill the insect.—*Acad. des Sciences: Les Mondes.* C.

New Laboratory Burner.—M. Godefroy uses four metallic cylinders, one within another; the first and the third are pierced with holes at their base. The spaces between the cylinders communicate, one set with two vertical pipes, uniting in a horizontal pipe below, the other set with another similar system. A piece of metallic net at the lower part, regulates the entrance of air.—*Nature.* C.

Weather "Probabilities" of the N. Y. Herald.—The predictions of storms, telegraphed from the *Herald* to Europe, are said to be fulfilled about six times out of seven. M. Le Verrier has expressed great satisfaction with their accuracy, and promised his cooperation in the work.—*Les Mondes.* C.

Factory Inspection.—The report of M. Engel-Dollfus, in the name of the Association for preventing accidents from machinery, institutes some comparisons between the methods of inspection in Berlin, Pomerania, Saxony, Coblentz, Cologne, and Treves, Switzerland, and England. A bill prepared for the consideration of the Swiss Federal Assembly, contains the following article:

"Every person who wishes to establish or carry on a factory, or to alter a factory already existing, must first obtain permission from the cantonal authorities. He must furnish exact statements as to the kind of industry which he proposes to follow; the plan, constitution and interior arrangement of his establishment; the number of workmen to be employed; and the nature of the materials which are to be manipulated; in order that the authorities may satisfy themselves that the requirements of the law have been all observed.

"No factory can be opened or set in operation without the formal consent of the government.

"When the nature of the establishment will involve special dangers for the healths and lives of the workmen, or of the neighboring population, the authorities will grant a concession only under certain reservations.

"If, during the running of a factory, grave inconveniences are noticed, which evidently compromise the lives and healths of the workmen, the authorities should, without prejudice to the concession which has been granted, require the proprietor to take such measures as are necessary to remedy the evil, and fix, with due regard to all the circumstances, the time at which the necessary ameliorations must be introduced.

"If any controversy arises between the cantonal government and factory-proprietors, concerning the execution of this article, the federal Council shall decide upon the appeal which shall be submitted to it.

"The federal Council is further authorized to issue general directions upon any of the points which are embraced in the present article."

The proprietors are represented as coöperating cordially with the Association, almost without exception, but the workmen are often reckless, and so set in old ways as to be slow to adopt any proposed improvements. Some idea of the character of the inspection may be found from the following summaries of the defects noticed in the year 1875.

The inspector for Pomerania reports examinations of a hundred manufactories, and changes in 137 cases, viz: 4 defensive guards to a piston rod, 5 balustrades about fly-wheels, 9 removals of work-benches from dangerous proximity to the engine, 7 balustrades added to staircases, 1 repair of a dilapidated stairway, 1 stairway condemned on account of proximity to machinery, 1 elevator wholly condemned, 11 elevators furnished with additional safeguards, 13 elevators condemned until they were supplied with automatic stops, 1 removal of a worn elevator chain, 8 guards at belt-opening through the floor, 1 guard for a crank near a passage-way, 2 dilapidated floors, 2 openings not guarded by balustrades, 12 defensive guards for wood-working machinery, 12 coverings for floor-shafting, 1 repair of an enlarged belt-opening, 6 special protections against danger from machines working under great pressure, 2 safeguards against danger in case of break in a wire cable, 2 reforms and removals of elevators, 2 violations of law in locating the purifying tanks of gas-works, 2 dangerous exposures to fire in gas-works, 1 defective gasometer, 2 violations of the provisions for the site of match-factories, 1 want of sufficient care to remove chlorine vapors, 7 workshops too crowded with workmen, 21 cases of defective ventilation.

The inspector for Saxony reports admonitions, as follows:

71 for faulty separation of steam-engine and fly-wheel, 70 for want of protection against danger from belts and cranks, 29 for want of protection against shafting and gearing, 16 for defective enclosure of elevators and hatchways, and 26 for want of balustrades to galleries or reservoirs, insufficient lighting, or non-enclosure of dangerous machinery.—*Bull. de la Soc. Ind. de Mulhouse, June*, 1877. C.

Chemical Physics.—The French Academy has been lately engaged in earnest discussion of some of the fundamental points of Chemical Physics. At the meeting of June 4, communications were presented on vapor-densities, by Sainte-Claire Deville; on the law of Avogadro, by Ad. Wurtz; on the atomic notation, in reply to M. Berthelot, by Ad. Wurtz; on atoms and equivalents, in reply to M. Wurtz, by M. Berthelot; on the law of Dulong and Petit, by M. Fizeau; and a reply to Fizeau, by Berthelot. Deville, in considering the cases where the vapor-densities vary with the temperature, states that "the movement of a material point, taken in the expanding material, may be accurately enough represented by a parabolic func-

tion of the second degree already employed by M. Fizeau."[1] He hopes to employ the resulting relations usefully in expounding some principles of Thermo-Chemistry. He admits that simple bodies may represent 1 or 2 volumes of vapor, and binary compounds may represent 2 or 4 volumes, but he questions the existence in a state of vapor of any substances which represent 8 volumes. Wurtz reports some experiments corroborating his opinion that chloral hydrate is dissociated at the moment of vaporization, defends his hypothesis, of a chemical union between the atoms of simple bodies, from Berthelot's charge of "mysticism," charges Berthelot with wishing to abolish the law of Dulong and Petit, alleges that the notation by equivalents "swarms with inconsistencies," and justifies his use of hypotheses for the interpretation of facts. Berthelot claims "that it is better to set forth the laws of chemistry under the form of determinate relations between quantities observable by experiment, such as gaseous densities and equivalents, instead of establishing such relations between representative chimeras, such as molecules and atoms;" he admits the law of Dulong and Petit as applicable to all simple gases, so long as they follow Mariotte's law and have the same coefficient of dilatation, "but the relations which exist between the specific heats of the solid elements are much more obscure, for in the solid state the heat not only produces molecular work which is the same for all bodies taken under the same volume, as in the gaseous state, but there is also special work, varying in different bodies, especially when elements are compared which have unlike physical properties;" and on all essential points he considers that the difference between himself and M. Wurtz is merely a difference in modes of expression. Fizeau, while disclaiming all right to judge upon chemical points, defends the physical accuracy and importance of the law of Dulong and Petit. Berthelot replies, admitting the rigor of the law and its dependence on the mechanical theory of heat, in all cases where the molecular states are strictly comparable, but claiming that in the passage to a solid state, new and unknown conditions are introduced which vitiate the law, or make it only approximately true.—*Comptes Rendus.* C.

Blue Ink.—Take Berlin blue, 6 parts; Oxalic acid, 1 part. Mix thoroughly into a soft paste, with water. Dissolve in rain-water, and add a little gum arabic.—*Fortsch. d. Zeit.* C.

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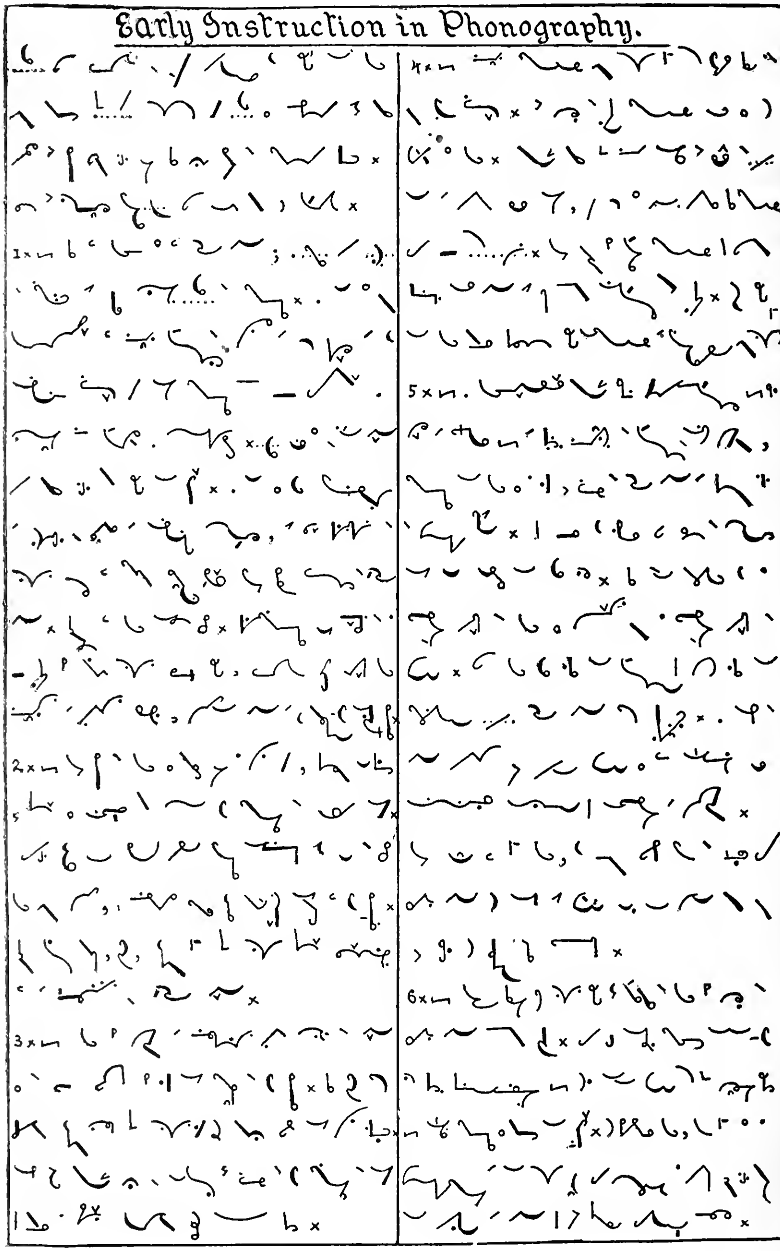
[1] See also *Proc. Amer. Phil. Soc.*, xvi, 507.


Early Instruction in Phonography.

EARLY INSTRUCTION IN PHONOGRAPHY.[1]

By Robert Patterson.

Those well qualified to judge are convinced that instruction in phonography should be begun at a much earlier age than is customary, and that the best results of the study will not be attained until it is made a subject of primary education. Some of the arguments for this view will now be set forth:

1. It is with phonographic as with ordinary writing—the principles are easy of comprehension, and the difficulties mainly those of practice. The hand has to be familiarized with the accurate formation of letters and word outlines, and that instinct acquired, which only practice can give, whereby the manual act follows on the mental conception. These ends, as to common writing, are best attained by instruction in childhood. The hand is then flexible and easily trained to habits and instinctive movements, and the slight daily drill of early years, with proper supervision, suffices for the satisfactory acquirement of ordinary writing. It would be the same with phonography, in the same circumstances. Daily practice, under the guidance of a good teacher, as a part of early school instruction, would qualify children to write phonography accurately and rapidly, and at least as soon as they would learn common writing, and without obstructing other needful studies.

2. If the study of phonography is postponed until a later age, it must be undertaken when the time is engrossed by many other branches of necessary knowledge. We contend that this is no sufficient reason for its neglect, and that under all circumstances phonography should be learned; but experience proves that it is pushed aside in the competition with other studies. It would be far better, therefore, that it should be taught at an earlier time, simultaneously with, and auxiliary to, ordinary writing.

3. Phonography, as a legible and extremely rapid method of writing, is of great utility as an aid in the pursuit of other studies. It is, therefore, very desirable that it should be mastered at an early age, so as to be made use of in the later education. Instead of then being made to interfere with the acquisition of other branches of

[1] Translation of article printed in audatype, on page 300.

knowledge, it becomes a highly valuable assistance in their attainment.

4. Accurate pronunciation should be early taught, or otherwise it is not apt to be ever acquired. Of the means of teaching pronunciation, none is so thorough as phonography. Being based on an accurate analysis of the sounds of our language, and representing sounds only, each word as written represents its pronunciation, whether good or ill. If the pupil has a false pronunciation, it will be detected in his writing, and the true can be enforced by the teacher. So that instruction in phonography becomes at the same time instruction in pronunciation, and for this reason should be early taught.

5. The phonographic writing signs being strict geometrical forms—straight lines and curves—and demanding accuracy of formation to ensure legibility, practice in phonography is an aid to the acquisition of ordinary writing, and, it may be added, of elementary drawing. It gives that steadiness, and yet freedom, of movement in the hand indispensable in those arts. It is of common observation that a graceful writer of phonography is likely to be a graceful writer of longhand. While phonography thus aids in forming, it also aids in preserving, our ordinary writing from deterioration. The necessity of writing rapidly, to which our common longhand is quite unequal, ends in many cases in making it ungraceful and illegible. If the young were taught phonography, that could be used for all occasions where swift writing was needed, and the longhand need no longer be put to a strain so destructive of its character.

6. Finally, it is only through early instruction that the possibilities of phonography, as a means of swift writing, can be developed. We do not anticipate perfection in any other art demanding technical skill, say in common longhand, or on a musical instrument, unless practice is begun in childhood. So as it respects phonography, if taught as an elementary branch, and in early youth, we may be certain that a rapidity would be attained, both in reading and writing it, of which at present we have no examples.

Hardening Zinc.—Stummer's *Engineer* recommends the addition of from ten to twelve per cent. of chloride of ammonium to melted zinc, in order to give it a considerable increase of hardness.—*Zeit. des Arch.- u. Ing.-Verein*, xxiii, 3. C.

Book Notices.

FRAZER'S TABLES FOR THE DETERMINATION OF MINERALS.—Revised Edition. J. B. Lippincott & Co. 1878.

The design of this work is excellent, and it will be useful to the beginner in mineralogical studies, and as an aid to teachers, but we expected in this revised edition corrections and improvements which we do not find. Thus "white" seems to be used throughout, except in one place, for both white and *colorless;* the streak given, is often that of impure varieties, and therefore often the streak of the impurity, and depending on the amount of the latter; thus the streak of ferruginous quartz is given as flesh red to blood red—of chrysocolla, "brownish-red; when pure, white." In the column of remarks, we think there should be given, as far as possible, the characteristics of the particular species, and not merely the blowpipe reactions of the elements given in the preceding columns, with which the student is presumed to be familiar before beginning determinative mineralogy; particularly there should be given, as is so well done in Prof. E. S. Dana's text-book of Mineralogy, the differences between the species in question, and those which it most resembles. Thus by the tables it would not be easy to distinguish minerals so commonly occurring as Calcite, Dolomite, and Magnesite in their varieties. Should another edition be called for, we trust these deficiencies may be supplied, and the book made far more valuable than at present.

WATER SUPPLY ENGINEERING. By J. T. Fanning, C. E. 32 full page and 148 other illustrations. 8vo, pp. 610. New York, 1877. D. Van Nostrand. Price, $6.00.

The want of such a treatise as this has so long been felt, that one is led to wonder that in this age of bookmaking some one has not taken it up sooner; but the delay may perhaps be, in some measure, compensated for by the able manner in which the author has accomplished his work.

The objects of the author in preparing this treatise, and which he has so successfully attained, as stated in his preface, are "to supply Water Commissioners with a general review of the best methods practiced in supplying towns and cities with water," * * * ; "to present to junior and assistant hydraulic engineers, a condensed summary of those elementary theoretical principles and the involved formulæ adapted to modern practice," * * * ; "to construct and gather, for the convenience of the older busy practitioners, numerous

tables and statistics that will facilitate their calculations," * * * ; "and also to present to civil engineers generally, a concise reference manual, relating to the hydrology, hydronamics, and practical construction of the water supply branch of their profession."

The work is divided into three sections: 1st, The collection and storage of water; 2d, The flow of water through sluices, pipes and channels; 3d, The practical construction of water-works.

In the first section, the author discusses in successive chapters the advantages of an ample water supply, both in its sanitary and financial aspects; the quantity required per head, with tables of the quantity supplied to a large number of cities in this country and in Europe. He gives much valuable information regarding the available supply to be obtained in any locality, under the heads of *Rainfall, Flow of Streams, Storage and Evaporation of Water, Supplying Capacity of Water-Sheds, and the Supplies from Springs and Wells.*

Chapters VIII and IX deal with the impurities usually found in water, and with the qualities of water supplied from wells, springs, lakes and rivers, with several tables of water analyses, and some special suggestions relating to the selection of potable water.

The principal portion of the second section of the book is occupied, as before stated, in the consideration of the Flow of Water under all the various and varying conditions likely to be met in practice; and the author, in addition to the formulæ adopted by himself, has placed, side by side, those of a large number of the best authors and experimenters, and has constructed many tables which must be of great value to the practical engineer.

The third section is devoted entirely to practical engineering construction, and deals very fully with those points upon which depend the safety and permanence of earth-works.

The chapters on Reservoir Embankments and Chambers, Partition and Retaining Walls, are particularly valuable.

The chapters on Mains and Distribution Pipes, and Distribution Systems and Appendages, derive their value mainly from the excellent arrangement of the matter and its many tables.

Chapter XXIII treats on the clarification of water, principally, from the engineering point of view, and gives a number of illustrations of filter beds, settling basins, etc.

Chapter XXIV is devoted to pumping water, but as this belongs more particularly to the mechanical engineer, and would require a large volume of itself for its proper consideration, only the general principles, and a few good examples, of pumping machinery could be given in the twenty-eight pages allotted to this subject.

The book is only moderately well indexed, but the mechanical execution of the book is good, and does credit to the publisher.

NOTE[1] ON THE CORROSION OF STEAM BOILERS BY THE SULPHURIC ACID IN THE SOOT DEPOSITED FROM THE SMOKE UPON THEIR SURFACES.

Translated from the *Annales des Mines*, of 1876, for the JOURNAL OF THE FRANKLIN INSTITUTE,

By Chief Engineer ISHERWOOD, U. S. Navy.

The Central Commission on Steam Engines had its notice called at the commencement of the year 1875, to the explosions of two steam boilers, one at the pits of Glenons, in the La Machine coal mine (department of the Nièvre); the other at the iron works of Ougrée, in Belgium; both of which are attributed to the deterioration of the metal by the sulphuric acid in the deposits left by the smoke on the iron plates of certain parts of the boilers.

Other facts of the same nature having since come to the knowledge of the Commission, it has thought that by making all the observations it has collected, the subject of a note, to be inserted in the *Annales des Mines et des Ponts et Chaussées*, they would be given the widest publicity, and attract the attention of engineers and manufacturers to the conversion under special circumstances of the sulphurous acid in the smoke from the furnaces of steam boilers into sulphuric acid; and thus direct inquiry to a question that has been but little studied. With this view the two accidents investigated by the Commission will be first described, and then the other observations made on the same subject will be reported.

I. *Explosion of the boiler at the pits of Glenons.*—The explosion at the pits of Glenons occurred under the following circumstances on the 13th of November, 1872: The boiler was cylindrical, with the fire-grate placed immediately beneath it. Below the boiler, and separated from it by a brick vault, was a feed-water heater, whose top nearly touched the vault. This heater was burst wide open at its front nozzle or connection, the rent extending along a horizontal seam, and perpendicularly to the two ends. The original thickness

[1] This Note, and the succeeding one, are the nearly integral reproduction of two Reports presented to the Central Commission on Steam Engines, by Mr. Hanet-Cléry, Engineer-in-Chief of Mines, during the session of February 2d, 1876.

of the metal, which, in the place that first yielded, had been 0·47245 inch, was found reduced to only 0·06693 inch, a thickness quite insufficient to resist a pressure of 85 pounds per square inch, under which the boiler was operated. The thinning of the metal was wholly on the outside, and extended, but in a much less degree, over all the upper portion of the heater. This deterioration, which was relatively rapid, as the boiler dated from 1867 only, was attributed by Mr. Douville, Mining Engineer, to the action of the oxygen and sulphurous acid in the gases of combustion in presence of the water leaked down from the boiler above, which, after percolating through the brick vault, dripped upon the comparatively cold heater,[1] wetting its upper portion and collecting principally along the horizontal seam joining its top and bottom plates, that prevented the water from running off. The smoke deposits on the top of the heater (which the position of the masonry hindered from being cleaned) were thus enabled to imbibe water, and the conditions became most favorable for the oxidation of the metal by the sulphurous acid. Mr. Douville took large scales of the oxide of iron from the corroded parts, and he therein found sulphur, but was not able to determine its state of combination.

II. In proof of this view of the case, the accident which happened at the iron works of Ougrèe, on the 30th of October, 1873, is most conclusive; in fact, the sulphuric acid was found in the smoke deposits, either in the free state, or combined in the sulphate of iron. The following are the circumstances of the explosion, as clearly set forth by the superintendent of that establishment.

The boiler was constructed in 1863, and consisted of three horizontal cylinders, two of which lay beneath the third, and were joined to it by connecting pipes. The two were of equal diameter, and the third was of larger diameter. All three were set with brick flues, and heated by the waste gases from three puddling furnaces. The flues were so arranged that the gases proceeding on entering in one direction, first enveloped simultaneously the entire circumference of one of the small cylinders, and one-half of the lower semi-circumference

[1] That part being at the extreme end where the smoke leaves the heater to enter the chimney, and where the cold feed-water enters the heater, Mr. Douville remarks that the aqueous vapor in the smoke could be condensed there and that the resulting water could add its action to the action of the water of infiltration in producing the oxidation by the sulphuric acid.

of the large cylinder; then returning in the opposite direction they enveloped simultaneously the entire circumference of the remaining small cylinder, and the remaining half of the lower semi-circumference of the large cylinder. There were thus two equal symmetrical and parallel flues, each containing at the centre, one of the small cylinders suspended by its two connecting pipes or nozzles from the large cylinder above; the interior of the three cylinders being in common by means of these nozzles. The top of each flue was formed by half of the lower semi-circumference of the large cylinder, the remaining two sides and the bottom being formed of masonry. The two small cylinders were wholly filled with water, and the large cylinder was half filled, its upper half containing steam only.

The small cylinder in the second flue, and at the end where the hot gases escape into the chimney, burst under conditions having the greatest resemblance to those just described in the case of the exploded feed-water heater at the pits of Glenons. The fracture commenced at, and closely followed, a horizontal seam; thence it continued vertically in two places, one in the solid plate and the other along the riveting of a joint. The thickness of the metal on the edges first torn was reduced to near 0·03937 of an inch. All the upper part of the small cylinder was corroded, the thinning diminishing progressively from the top. The deterioration was entirely on the outside.

Two specimens of the deposits left by the smoke on the injured iron have been analyzed; they gave between 52 and 53 per centum of sulphate of iron. One gave 1·42 per centum of free sulphuric acid, the other gave 12 per centum nearly. The deposits formed on the rest of the boiler also contained sulphuric acid, but in notably less quantity, and no sensible deterioration of the metal had resulted from it.

The action is explained in the following manner: During the working of the furnaces the deposits are thrown down in the pulverulent state, and quite dry; but on the extinction of the fires the external air charged with humidity, fills the flues, and by lengthened contact makes the soot pasty with moisture. The conditions are now most favorable for attacking the iron, and its oxidation by the sulphuric acid commences. The corrosive action then continues, during the whole time the boiler is out of use, on those parts which are not cleaned; while, on the contrary, it is not sensible on the parts from

which the deposits are frequently removed. Now the thin and torn part of the exploded small cylinder was exactly in the first of these cases: it was backed against the vertical wall of masonry, separating the two flues, a place very difficult of access, and consequently examination and cleaning were neglected.

III. Some examples of exterior corrosion in consequence of the condensation of the aqueous vapor in the smoke on the cold parts of boilers, have been pointed out by Mr. Meunier-Dollfus, director of the Alsatian Association on Steam Boilers. (See Bulletin de la Société Industrielle de Mulhouse, 1871.) We cite, particularly, the observations made on the boilers in the shops of Mr. Charles Kestner, at Thann.

These boilers were two in number, and each was composed of four horizontal cylinders, one of which was of large diameter, and the remaining three were of small diameter and suspended below it by two connecting nozzles or pipes each. Between these boilers, and imbedded in the same masonry, were six feed-water heaters, arranged in pairs, each pair being on a different level, but in the same vertical plane. The gases of combustion circulated around the entire circumferences of the three small cylinders, then in one direction, beneath a portion of the circumference of the large cylinder, returning in the opposite direction beneath another portion, from which they continued to the feed-water heaters, passing over each pair successively, from high to low. The feed-water, during its passage through the heaters, moved in the reverse direction.

A single boiler was most often in use; it was worked night and day, but with a less rate of combustion during the night.

In an experiment the feed-water was found to enter the lowest pair of heaters with a temperature of 68° Fahr., and to leave them with a temperature not exceeding 86° Fahr.; it left the highest or last pair of heaters with the temperature of 122° Fahr. On the other side the temperature of the smoke, when leaving the lowest or last pair of heaters, did not exceed 302° Fahr. during the day, and 212° during the night. After two years' use, under these conditions, the heaters were injured, and at the end of six years, although the metal was of excellent quality, its thickness was so much reduced that they had to be renewed.

The corrosion was principally on the cold or but little warmed portions of the heaters, and had, for first cause, the sulphurous acid dissolved in the water of condensation deposited from the smoke. It was ascertained that, in presence of the air and of this watery acid, there was first oxidation of the iron and then formation of the sulphate of the oxide of iron.

IV. Some observations on that cause of the destruction of boilers have been made in the Department of the North, by Mr. Cornut, engineer-in-chief of the Association of the Proprietors of Steam Boilers in the North of France, at Lille. He has frequently discovered exterior corrosions, which seemed to him attributable to the smoke, and he found them strictly limited to the portions of plate kept wetted from any cause—leaks, infiltration of water, etc.

V. We will close with the following remarks: The transformation of sulphurous acid into sulphuric acid, by the action of water, or of the vapor of water and of air in presence of a base or of a metal, is not a new fact. For a long time advantage has been taken of this property of sulphurous acid, either for disinfecting the neighborhood of certain metallurgical establishments or for the treatment of particular ores. In illustration of the last, we can cite notably the process of Mr. DeLamine, for the manufacture of the sulphate of alumina, at Ampuis (Belgium), and the treatment of some oxide of copper ore, on the banks of the Rhine.

It would seem that these old applications ought long since to have drawn attention to the possibility of the corrosion of steam boilers by reactions of a similar kind; but nothing was done, and so far as concerns that special problem—if the general fact is now known—there still remain the details for investigation, some of which are not wanting in practical importance.

CONCLUSIONS.

The results of all the preceding observations can be summed up thus:

When the smoke deposits on boiler surfaces distant from the furnace are rendered moist by any accidental cause, the sulphurous acid in the gases of combustion determines the attack upon the metal by the formation of the sulphate of the oxide of iron.

The attack can take place, while the boiler is in use, on such of its metallic surfaces as may be wetted by leakage from the boiler itself, or by water infiltrated through the masonry, or derived from the condensation of the aqueous vapor in the gases of combustion by contact with surfaces relatively cold. It can also be produced while the boiler is out of use, by means of the humidity of the air in the flues.

These different origins of the corrosive action, point out the precautions to be taken for preventing its destructive effects. They are only those which should be adopted for the preservation of any apparatus, viz., careful construction, thorough cleaning, and maintenance in good repair.

ANALYSIS OF THE REPORTS OF THE OPERATIONS OF THE BELGIC ASSOCIATION FOR THE SURVEILLANCE OF STEAM BOILERS, DURING THE YEARS 1873–1874.

Translated from the *Annales des Mines*, of 1876, for the JOURNAL OF THE FRANKLIN INSTITUTE,

By Chief Engineer ISHERWOOD, U. S. Navy.

As the reports made of the operations of the Belgic Association for the Surveillance of Steam Boilers contain a very complete investigation of the different causes of the deterioration of boilers, a detailed extract will be interesting, leaving to the Chief Engineer of the Association the responsibility for his observations and opinions.

The association commenced on the 30th of December, 1872, and its operations extend over all Belgium. At the end of 1874, that is to say, in the second year of its existence, the number of boilers under the association rose to 1031; it was 827 at the end of the first year. 485 boilers were examined interiorly during 1873; 278 were in need of repairs, of which 64 required to be immediately taken in hand by reason of the danger they presented. In 1874 the number of boilers examined interiorly was 607. Many of these examinations revealed serious defects, for which 62 boilers were at once repaired.

The defects stated were separated, according to their nature, into several categories. These categories, and the number of boilers per category, were as follows:

Nature of the Defects.	Number of Defective Boilers.	
	1873.	1874.
Interior corrosion, . .	66.	148.
Exterior corrosion, . .	Not indicated.	111.
Cracks or fractures, . .	Not indicated.	76.
Divers causes: Too hot a fire, scale, etc., . . .	Not indicated.	Number not sufficiently indicated.

The reports give some observations of detail regarding the nature of the defects, as well as concerning their origin or causes. We reproduce the most important:

I. INTERIOR CORROSION.

This kind of corrosion sometimes attacks large surfaces uniformly; sometimes it appears by isolated cavities more or less abundant. The first seems to be the oftenest produced by the use of corrosive water or of scale-preventing remedies. Occasionally it is due to the bad planning of the boiler, as, for example, in those whose design permits the formation of pockets or steam spaces in the feed-water heaters. Of the second, which is stated to be very frequent, the report of 1874 remarks as follows:

"There are often found small isolated cavities in the middle of an otherwise intact plate. These cavities are nearly circular, and have a depth and diameter increasing with their age. They are filled with a black powder composed, in great part, of the oxide of iron derived from the rusted metal, of sulphates and carbonates deposited from the water in vaporizing, and of a very small quantity of silex. Sometimes they are capped by a yellowish-colored dome."

In some boilers three or four years suffice to perforate a plate, and a dozen years are rarely required.

Occasionally a boiler attacked in that manner presents cavities of all sizes—from those just commencing, up to the largest. Occasionally, too, the cavities are all of one or two sizes, as though they dated from one or two well marked epochs.

Up to the present time this species of corrosion, which we will call the vermicular, has been observed only exceptionally in plates on which the water is kept in ebullition or agitated. It is found frequently in boilers with feed-water heaters, and in this case the principal cylinders are completely spared, while the coldest of the heaters is the most attacked.

The not heated portions of the boiler and feed-water heaters (for example, the portions resting on the masonry or projecting from the exterior of the furnace), offer strong corrosions of this nature.

When these cavities, instead of being widely apart, are close together, they can form, by their union, a line of fracture.

The engineers of the association have made several analyses, simultaneously, of the feed-water, of the scale produced by it, and of the residues which fill the cavities. Their researches, without reaching an absolute conclusion, have led them to the following presumptions:

Corrosion, under these circumstances, does not seem to proceed from any real acidity of the water, but is exclusively due, according to all appearances, to the action of chlorides or of alkaline salts contained in the water in very small quantities. In five analyses, the products of corrosion contained chloride of iron, which leads to the belief that, in this case at least, chlorides have been formed. It is not impossible that, in other cases, chloride of iron may have been produced, but it would disappear by dissolution in the water of the boiler.[1]

II. EXTERIOR CORROSION.

The exterior corrosions are, according to the reports, one of the greatest causes of the destruction of boilers. Neglecting those which are produced by well-known causes, such as the contact of the metallic plates with the wet masonry of the boiler-setting, and leaks at rivets, seams and cracks, attention is particularly called to the observations relating to the action upon the plates by the products of combustion, an action which has been investigated with much care.

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[1] The oxidizing action of the chlorides of magnesium and of calcium contained in the feed-water of boilers, is a well-known fact. These chlorides are decomposed by the heat of the boilers, and attack either the metallic surfaces in contact with water, or those which are in contact with the steam.

After a boiler has been in use for some time, says the Report of 1874, all the surfaces in contact with smoke are covered with a deposit of soot and ash, containing corrosive matter. This deposit has a different appearance, according to its distance from the furnace, and it varies also according to the kind of coal consumed and according to other conditions as yet but imperfectly understood. Its composition changes on being exposed, after the extinction of the fire, to atmospheric air containing aqueous vapor. Neglecting the surfaces exposed to the direct action of the fire, and confining our observation to those at a moderate distance from it, we find the deposit which covers them to consist of three distinct layers. Immediately upon, and strongly adherent to, the metal, is an extremely thin layer of grayish matter, very acid and astringent. Above it is a very acid and astringent black layer. Finally, over both is a white or pinkish layer of matter of extreme tenuity; it is soft to the touch, and, though nearly insipid immediately after the extinction of the fire, soon becomes acid and astringent. This last layer is not found on those surfaces where the temperature of the smoke is low.

Twenty-five analyses were made on specimens taken from these different layers at different intervals of time from the moment of extinguishing the fire; some of the specimens were taken from near leaks. All these analyses showed the presence of free sulphuric acid, or of ferruginous sulphates, or of oxide of iron, resulting from the decomposition of the sulphate of iron at a high temperature.

If, in a mixture of water and of the lower layer of the deposit, an iron blade be plunged, it is vigorously attacked with disengagement of hydrogen and formation of sulphate of iron. Nothing can be more natural than the production of this salt, at the contact of the layer and of the metallic plates, when the boiler becomes damp. The entire thickness of the deposit becomes impregnated by imbibition with this sulphate and with free sulphuric acid. On those parts of the boiler surfaces, however, where the smoke has a sufficiently high temperature, and the soot is thick enough to receive the temperature of calcination, the upper layer burns, under the action of the oxidizing gases, and the salts of iron decompose and form the white and pinkish matter which covers the deposit in this case.

Such, according to the engineer-in-chief of the association, is the explanation of the special appearances and varied composition of

the deposit found on the surfaces of the boiler which are beyond the direct action of the fire.

As long as the boiler is in action, corrosion takes place only on the plates contiguous to leaks, or to damp masonry, or on the plates whose temperature is low enough to condense the aqueous vapor in the smoke; the others are not attacked. But when the fire is withdrawn and the boiler is no longer in use, then the acid formed, and the sulphates of iron and of alumina, attract the humidity of the atmosphere, and when they have attained a certain degree of dilution, the plates commence and continue to rust until only the oxide of iron remains. When a boiler has been out of use over eight days, the corrosion will have become more or less strongly marked, according to the amount of humidity in the air, and in the masonry of its setting.

The influence of the nature of the coal consumed on the degree of corrosion has not yet been ascertained.

III. CRACKS.

Under the head of cracks we do not include those which occur at the edges of plates or in the bends of the flangings, but limit ourselves to those that have been observed to follow through the transverse rivet holes in the lower parts of boilers, some of which cracks have lengths of sixteen, twenty, and even fifty inches. When it is considered that along these lengths the plates are only held by the friction due to the pressure of the rivet-heads—a pressure which is itself lessened by the slipping of at least one of the plates—we are led to ask why explosions do not immediately result from cracks of such size. The Report essays an explanation by remarking that in proportion as the lower plates are strongly heated, they are compressed by reason of the resistance opposed to their expansion by other colder plates. What seems to demonstrate this fact is that nearly all the cracks at the bottom of boilers close when hot and re-open when cold. The danger, however, re-appears as the cooling commences, and it is credible that many of the explosions which have occurred as the fires were dying out, were due to this cause.

IV. DIVERS CAUSES: TOO GREAT INTENSITY OF THE FIRE, SCALE, ETC.

In a great number of boilers formed of connected cylinders (*chaudières à bouilleurs*) which have been found liable to be burnt, the burning ordinarily occurred at one place, and this place always had a

constant juxtaposition to the front nozzle or short pipe connecting the boilers. This effect is considered due to the accumulation of sedimentary debris carried by the currents that flow regularly across the nozzles of communication, and deposited by the eddy in the parts relatively tranquil.

The last subject treated by the Reports is boiler-scale, but only a single case is examined: that of the lime-soap deposits due to feeding the boilers with water of condensation from the engines.[1] The injurious action of these deposits is shown, and the fruitless attempts described that were made in Belgium to avoid them by the use of tubular apparatus, in which the greasy steam is kept from mixing with the water. Finally, the use of mineral oils for the lubrication of the cylinders is recommended as éfficacious—a method adopted some time since by the British Admiralty for the steam cylinders of their vessels.

After having thus reviewed the different defects revealed, during two years of examination, by the boilers under the surveillance of the Association, the Report of 1874 terminates with the following general observation:

"Because of the little value of the hydraulic test as the sole guarantee of the strength of boilers, periodical examinations by experts are necessary of their interior as well as of their exterior."

Vitreous Phosphate of Lime.—The acid phosphate of lime, described by M. Sidot, is crystallized under the influence of heat. If exposed to a very high temperature, it becomes perfectly vitrified, abandoning part of its elements and descending probably to the condition of tri-basic phosphate of lime, $3CaO, PO_5$. It has great refracting power, its index being 1·523; its density, 2·6. It can be worked like common glass, to form lenses, prisms and brilliants, with a strass-like lustre. It resists cold acids, but is attacked by boiling acids and by potash. This property may render it valuable in the art of engraving on glass.—*Acad. des Sci.; Les Mondes.* C.

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[1] The Central Commission in 1874 investigated the accidents attributed to this kind of incrustation. When these soaps are deposited, even in very thin pellicles, on the water-heating surfaces of boilers, they prevent the contact of the water and metal which thus becomes overheated, burnt and ruptured.

ON A NEW TYPE OF STEAM ENGINE, THEORETICALLY CAPABLE OF UTILIZING THE FULL MECHANICAL EQUIVALENT OF HEAT-ENERGY, AND ON SOME POINTS IN THEORY INDICATING ITS PRACTICABILITY.

Presented at the Nashville meeting of the American Association for the Advancement of Science, 1877.

By Prof. ROBERT H. THURSTON, Vice-President.

[Continued from Vol. lxxiv, p. 266.]

XIV.—In order to show that heat may be converted into work to any extent, and without regard to the temperature of surrounding bodies, we will trace the process in two cases, viz.:

1. Where the working fluid is a permanent gas.
2. Where a working substance subject to change of physical state is used; for example, steam.

Suppose a working cylinder provided with a tight-fitting piston, the cylinder to be of indefinite length, and the working fluid to be on one side of the piston and a perfect vacuum on the other side. It is evident that expansion may go on indefinitely in such a cylinder, and that the temperature of surrounding objects will have no influence on the extent of such expansion, or upon the completeness with which heat can be converted into work. The working fluid and its work are absolutely independent of everything external to the cylinder in which the transformation of heat into mechanical energy is going on. There is no natural limit to the process of conversion. The piston being free and offering no resistance to motion, we may suppose the expansion to continue until the working fluid, which we will here assume to be a permanent gas, has lost all expansive force, and until all its original heat-motion has been converted into mechanical energy and transmitted to objects external to our prime mover.

The conclusion of the operation leaves the molecules of the gas diffused through a vast space, absolutely at rest,[i] and without vibratory motion. Had not the heat originally contained in the mass

[i] This may be too unqualified a statement. It is not certain that all heat-energy can be removed from a fluid by expansion. It is possible that an indefinite amount of energy of rotation may be retained after expansion shall have removed all energy of motions of translation of the molecules.

been expended in doing work, the magnitude of this space would evidently have been infinite, and the particles, when they had lost all vibratory motion, would have acquired a velocity of translation in lines parallel to the direction of motion of the piston, equal to the velocity due the height through which their original heat-energy would have been sufficient to have lifted them, and equal to the velocity of the particle in its orbit of heat-motion. As, however, this heat-motion has been converted into mechanical energy, the space through which the gas may diffuse itself is restricted.

Now, the removal of a particle from one point in space to another, requires no expenditure of energy. The work done on the particle, in giving it its maximum velocity in transit, is restored by it while it is being again brought to rest. It may thus be possible, in our supposed case, to gather up all these particles and to collect them about their common centre of gravity, where they will occupy the volume of the gas in its solid state and at absolute zero. If this had been done without collision of particles, no energy will have been expended and no work will have been lost. The mass may now be transferred to the reservoir, at its original starting point, by the expenditure of an amount of energy bearing a less proportion to the energy which has been converted into work as the now indefinitely small volume bears to the volume of the gas when it first issued from that reservoir; the amount will be insignificant. The operation just traced may thus be repeated indefinitely. The efficiency of our engine is unity, and it is perfect in every sense.

It needs no further reasoning to prove that the temperature of surrounding bodies has no influence upon the operations here indicated, and that it is a matter of no moment what may be the temperature of the place at which this work has been done. It is further evident that, if the upper limit of temperature in this example had been the temperature of the earth's surface at that place, and if the working substance were air, the reservoir might have been the atmosphere, and the operation described would, if continued indefinitely, result in the conversion of all heat-energy into mechanical energy, and the cooling of the earth down to the absolute zero of temperature. Were it practicable to carry on this operation, and to apply the mechanical energy resulting from it to the acceleration of the earth's motion in its orbit, its velocity would be increased something like one mile per second (we assume the mean temperature of the earth at 1500° Cent., and its specific heat at 0·2).

XV.—Next, suppose the same operation to be repeated (and in the same manner), using as a working substance a fluid which loses the original physical condition while expanding, and, like steam, condenses as it expands. In this case, the particles of the fluid, instead of being indefinitely dispersed, are capable of but a limited expansion. At each instant, a portion of the vapor assumes the liquid state, surrendering its latent heat of vaporization to the uncondensed portion of the gas, to be transformed into work. Thus an accumulation of liquid takes place in the cylinder which becomes very considerable, even in engines operated within very usual ranges of temperature. Conceive this operation to continue until the limit is reached as before. There will now remain in the steam cylinder a mass of ice at the absolute zero of temperature and a minute quantity of matter at the same temperature, but with its particles widely separated, as in the preceding case. The great mass of the working substance has, in this case, been collected by the process of condensation during expansion, and thus nature has done here what, in the other case, must have been done artificially. It now remains to return to the reservoir the solid mass. This is done, as before, with no great expenditure of energy. The small quantity of dispersed particles may be gathered up and restored, as in the case of the permanent gas, or it may be rejected from the system as of no appreciable value, as may seem best. The process being completed, the system is in condition to permit the commencement of a new cycle. It is evident that the efficiency of this ideal engine is, like that of the ideal engine using a permanent gas, perfect.

XVI.—The practical difficulties which stand in the way of the engineer who endeavors to realize the conditions described, are apparently insuperable. Yet this impossibility of realization is due, simply, to the existence of natural conditions which are comparable, in their influence, to the action of repellant central forces. We may conquer them in a certain degree by the exertion of any given amount of skill and intelligence; but, as we advance, the difficulty becomes more and more nearly insurmountable by finite power, and the perfect realization of the conditions and of the efficiency first idealized is only attainable by the exercise of an apparently infinite intelligence and power. Perhaps a better and more encouraging view would be given by the statement that we may expect to approximate to the

realization of the efficiency of the ideal perfect engine more and more closely, as we advance in scientific knowledge and in constructive skill, without limit. It is therefore proper to inquire how far we are limited in this progress by conditions which are now common in the practice of steam engine construction. This we will presently do.

XVII.—Thomson appends to his proposition (which has been called an axiom) the following note:

"But if this axiom be denied for all temperature, it would have to be admitted that a self-acting machine might be set to work and produce mechanical effect by cooling the sea or earth, with no limit but the total loss of heat from the earth and sea, or, in reality, from the whole material world."

Yet we have already seen that such an engine might, by some intelligence, mighty, but not necessarily infinite, be set at work to produce mechanical effect by cooling sea, earth and air. We can see that Omnipotence may thus transform all the heat-energy of the universe into mechanical energy. The "Creation" was either such a transformation of previously existing heat-energy, or an actual production of something from nothing. Either process would accord with all that is taught us by either science or revelation.

Trace, again, the cycle of our ideal engine: a certain weight of working substance is contained within a reservoir, whence it issues, driving a heat engine in which all its available energy is transformed into mechanical work. Restored to the reservoir, it there receives a new stock of heat from the surrounding bodies, which constitute a part of the material world, and another cycle succeeds. This continues until all the heat of surrounding objects, and all they can withdraw from other bodies, is exhausted, and an equivalent amount of kinetic or of potential energy has been produced. *The machine may go on and abstract all the heat from the universe.*

Again, suppose the engine to derive its heat from the combustion of fuel within its reservoir. It is now absolutely independent of all external bodies, so far as temperature is concerned, and knows nothing of so-called limits; its only limits are the temperature attainable by the combustion of its fuel on the one hand, and the temperature at which heat-motion ceases on the other. It may be considered as enclosed within a chamber absolutely impervious to heat and may be placed in a part of the universe devoid of heat, or in a place where it will be surrounded by the heat of a glowing sun; it will, if it does not

exhaust its stock of fuel, work on under all such variations of external conditions with unvarying efficiency. This complete separation from external temperatures is one of the most familiar problems of the engineer in his management of the ordinary steam engine, of the air or gas engine, or of any heat engine.

The universe (taking a glance at a wider cycle) is independent of our engine working on heat-energy derived from fuel, so far as regards its stock of heat-energy. The machine receives a certain amount of energy as heat and discharges it as mechanical energy. This mechanical energy is all, directly or indirectly, returned to its original form of heat-energy. The heat received from surrounding space and stored in our coal-beds, is, through the engine, revived, changed in form, then changed back into heat again, and finally thrown back into space.

Thomson's qualification of his "axiom" does not, evidently, confirm the principle which he has enunciated Our self-acting machine *might* cool down "the whole material world."

XVIII.—The practical difficulties which stand in the way of the engineer who attempts to effect the realization of either of the two classes of perfect engine which have been described, can now be easily anticipated, and we may even, to a certain extent, determine how we may best proceed to attack them.

Type A is seen, at a glance, to be an utterly impracticable form of engine. Using a permanent gas as the working fluid, we could not possibly find space for the expansion of the gas to absolute zero. Could we find space, the mean pressure would be so low, and the magnitude of the engine so great, that the resistances due to friction would absorb more than all of the energy developed. But even supposing these two difficulties less absolutely insurmountable, we should still be unable, by any known process, to gather up the scattered particles of the fluid without producing collisions among them, which would generate heat and compel the expenditure of energy in the restoration of the condensed gas to the reservoir. In all known methods of condensation, as in the compression of air for use in mining and other machinery, the heat developed is equal in amount to that given out by the gas in expanding. We are thus practically brought to a limit, in the expansion of the permanent gases in heat engines, at which the *useful* transformation of heat into mechanical energy

must cease. This limit is that assigned by Thomson to the ideal engine. If, at some future time, a working fluid and a method of operation shall be found which will enable us to bring the temperature of the expanding substance to atmospheric pressure at less than atmospheric temperature, the limit will be moved farther toward the zero. All known or probable modifications of Type A will be likely to transfer the machine to either Type 2 or Type 3.

The use of other working substances than the permanent gases does not seem likely to overcome entirely the difficulties pointed out as inherent in the use of those gases. It is, nevertheless, perfectly obvious that condensable fluids may prove better working substances than the permanent gases, in virtue of the property possessed by them of self-aggregation. Such fluids will evidently demand less space into which to expand; and the economy of space will rapidly become more marked as the absolute zero is approached. If, at some future time, a fluid shall be discovered which, possessing great volume at high temperatures, like steam, shall become wholly liquefied at ordinary temperatures, when expanding against a resistance, and on reaching a moderately low pressure, the efficiency of the engine will become more nearly perfect, probably, than in any practicable form of even theoretically perfect engine worked by a permanent gas. It is evident that the property which it possesses of condensing with expansion, while doing work, is an exceedingly important and valuable quality of the vapor of water, considered as a working substance for heat engines.

No way has yet been devised, however, of making a steam engine of Type A. Assuming it to be possible to make such an engine, using steam of 75 pounds pressure by gauge, expansion is supposed to go on, in this case, until the fluid, by the conversion of all its heat into work, has become first liquefied and then solidified. We may easily estimate the efficiency of such an engine, working without loss by friction, or other causes. The work done per pound of steam admitted at 75 pounds pressure, and at a temperature of 320° F. (160° Cent.), would be 910,557 foot-pounds; the work expended in the removal of the ice against atmospheric pressure, would be something less than $38\frac{1}{2}$ foot-pounds; the efficiency would be $(910{,}557 - 38{\cdot}5) \div 910{,}557 = 0{\cdot}9999 = E$. All heat originally existing in the fluid having been used in doing work, the rejected solidified matter would absorb heat from surrounding bodies, and thus a

certain portion of energy would be acquired by cooling down those objects. Assuming the engine perfect, structurally, and thus free from friction, the upper limit of temperature, as has already been indicated, need not exceed that of the surrounding bodies. In the actual engine, the duty would be diminished immensely by frictional and other losses.

Complete utilization of all heat is not practicable with the heat engine of Type A under any known, or even conceivable, conditions in actual construction.[1]

XIX.—It remains to consider the possibility of securing maximum efficiency in actual engines, by the adoption of Type B of Class 1. In this form of engine, all heat rejected from the working cylinder is retained in the system and is restored to the reservoir, thus securing complete utilization of all heat which leaves the machine. Nothing escaping, except in the form of mechanical energy, there can be no waste, and the efficiency of the machine must be unity. The engine is a perfect machine for transforming heat into work.

It has just been seen that a practical and probably insurmountable difficulty arises in the attempt to make an actual engine of Type A, even using a condensible fluid as the working substance, in the necessity of removing not only the ice deposited, but also of gathering up the widely-diffused molecules and restoring them to the reservoir, without giving them vibratory motion, and thus expending upon them an amount of energy equal to that which they had given out during their expansion.

If it were possible to find a working fluid of such character that the desired conditions may be partially realized, and at a comparatively high temperature—that of surrounding bodies—and that the condensed portion of the substance may be returned to the reservoir, the vapor remaining being discharged into the atmosphere, such an engine would evidently be a simple modification of the well-known

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[1] NOTE.—The two kinds of fluid, working in engines of the Class A, are seen to give two characteristic products of the two known processes of abstraction of heat from fluids: 1. Forcibly compress the fluid, removing the heat of compression as rapidly as it is generated; the product is, after all heat has been removed, a mass of maximum density, probably solid in all cases, and at the absolute zero of temperature. 2. Abstract the heat contained originally in the mass, by causing its expansion against a resistance; the product is a diffused mass, without tension, of minimum possible density, and at the absolute zero of temperature.

high-pressure expanding non-condensing steam engine. In the latter the steam is largely condensed by expansion as a working fluid, and the water is often, and may be always, returned to the boiler. The uncondensed portion is discharged into the atmosphere. To convert this engine into a machine of Class B, it will be necessary to find a way of restoring *all* rejected heat to the boiler.

Type B, in which all unutilized heat is restored to the reservoir, comprehends engines of two very different kinds. These are:

1. Heat engines in which the rejected heat is transferred from the mass of working substance discharged from the working cylinder at the end of the stroke of the piston, to a mass of metal or other heat-absorbing material, and from the latter again transferred to another and a new charge of working fluid which is about entering the reservoir to take up a new stock of heat energy.

2. Heat engines in which, as in the ideal engines already described, the rejected working fluid itself, with its contained unutilized heat, is all returned to the reservoir.

XX.—Engines of the first of the two kinds into which Type B is here divided, and in which the working fluid is usually air, have frequently been designed. The mechanism by which the heat is stored and restored by transfer has been called the "Regenerator." Engines having regenerators have always been supplied with air as a working fluid. The regenerator consists of a mass of metal, usually made up of a collection of conveniently disposed sheets or wires, into which or through which the rejected gas is discharged, and through which or from which the entering charge of the working fluid passes on its way to the cylinder. The mass is heated by the transfer to it of heat from the rejected charge, and this heat is returned to the entering charge to be more or less thoroughly utilized by expansion at the succeeding stroke.

The regenerator never operates with more than approximate thoroughness. The time allowed for the transfer of heat from the regenerator is not just equal to that given for absorption by it. The complete transfer of all heat, and with equal rapidity in both directions, demands an equal mean difference of temperature between the metal and the gas, urging the flow of heat in the two directions. This is not secured, and the regenerator either continually warms up by the accumulation of heat, or it acts very inefficiently. In the air engine of Stirling, in which this device was first used, about

1820, the amount of lost heat was still very considerable. The entering charge of air is itself heated before passing through the regenerator, and is thus prevented from taking up additional heat readily and promptly. The rejected charge is sent through the regenerator with very great rapidity and is rapidly expanding as it passes. It is not given time enough to discharge its heat into the metal received, and it necessarily retains a considerable proportion as latent heat of expansion. Nevertheless, air engines fitted with regenerators have sometimes proved to be very efficient. The engines designed by Ericsson for the steamer of that name were found by Prof. Norton to have developed their full power (300 H. P.) with a consumption of but 1·87 pounds of coal per hour and per horse-power. The transfer of heat from the fuel to the working fluid was here found to be, as is always the case with this class of engines, very ineffectively secured. The gases are too nearly perfect non-conductors to permit rapid absorption or discharge of heat; and this fact is one principal cause of their inefficiency; it so greatly reduces the efficiency of their furnaces that the net efficiency of the machine becomes very much less than it would be were the furnace as effective as are steam boiler furnaces. It is evident from what has been stated that the regenerator, as applied to engines having permanent gases as their working fluids, does not yield a satisfactory economy by storing and restoring rejected heat.

The regenerator is entirely inapplicable to engines in which steam and other saturated vapors are employed. The rejected heat, in these engines, is principally conveyed from the working cylinder in the form of latent heat of vaporization, and can only be removed from the exhausted charge by the condensation of the steam. But this condensation involves the degradation of the rejected heat to a temperature at which it is no longer transferable to the entering charge of the working substance. The use of a regenerator is therefore out of the question in engines in which vapors of liquids similar to saturated steam are employed.

It is, however, possible to secure a partial saving of heat rejected from one such engine, as the steam engine, by using, as an absorbent of that heat, a liquid having a boiling point at a temperature considerably below that of the liquid formed by the condensation of the first used vapor. The transfer of the heat rejected from the first engine to the liquid contained in a reservoir forming a part of the

second engine, results in the condensation of the steam in which it was originally contained and the simultaneous vaporization of the second liquid. The latter is then used in the production of power by the utilization of a part of the heat thus preserved. Could a series of substances be found thus related to each other, this process could be continued indefinitely, or until the available energy ceases to be competent to overcome frictional and other resistances. The engine which formed the terminal of the series would waste all heat rejected from its cylinder. Such a combination as is here described has been made, two engines being used, and has been known as the "Binary engine." The first of the pair has been worked by steam, and the second by the vapor of ether, of chloroform, or of the bisulphide of carbon. The efficiency of the combination has considerably exceeded that of the steam engine; but it has not been sufficient to compensate the practical difficulties met with in the construction, and especially in the operation, of such engines.

Microscopic Mineralogy.—Father Renard has contributed to the Scientific Society of Brussels, a paper on the microscopic analysis of rocks and of mineral cavities. The latter portion of his subject is of special interest. Cavities are often found in crystals, containing liquid, with a movable bubble. By warming the crystals carefully, the bubble is found to disappear at a temperature of about 300° C. (572° F.), which is, therefore, regarded as the probable temperature at which the liquid was enclosed, and the rock solidified. Petroleum, sea-salt, and liquid carbonic acid, as well as water, have been found in these cavities, and the supposed temperature of consolidation has been confirmed in various ways. Empty, vitreous cavities are often found, showing that, while quartz and granite rocks have been deposited from watery solutions, porphyries, trachytes, etc., have been fused.—*Les Mondes.* C.

"Narrow-Gauge" in Germany.—Buresch (*Zeits. des Archit.- u. Ing.-Ver. in Hannover*, Heft 2, 1877) and Plate (*Wochen. des Oester.-Ing.- u. Archit.-Ver.*, June 23) give interesting accounts of a new narrow-guage railway in the grand-duchy of Oldenburg, connecting Wederstede with the main Oldenburg line at Ocholt. The neighboring district is entirely agricultural, population sparse, freight small, fares low, land poor, and yet, thanks to rigid economy in construction and management, the investment "*pays.*" C.

THE CONVECTION THERMOSCOPE FOR PROJECTION.

By Le R. C. Cooley, Ph. D.

By means of the *Convection Thermoscope*, devised in 1871,[1] and that form of it described in this Journal, vol. lxx, p. 134, it is possible to illustrate many of the most delicate effects of heat, with success otherwise to be attained only by means of a sensitive thermopile and galvanometer. But to make it most useful for purposes of instruction, its delicate indications must be projected on a screen. In the earlier forms of the instrument, this was accomplished by sending a beam of light through the chamber lengthwise of the needle. The accompanying cut represents a later form, in which the obvious disadvantages of that method are avoided, and results obtained which seem to be sufficiently satisfactory to warrant a permanent record.

For a full description of the instrument, and the theory of its action, the reader is referred to the articles above mentioned. A brief reference to its most important parts will, in connection with the cut, be sufficient for present purposes.

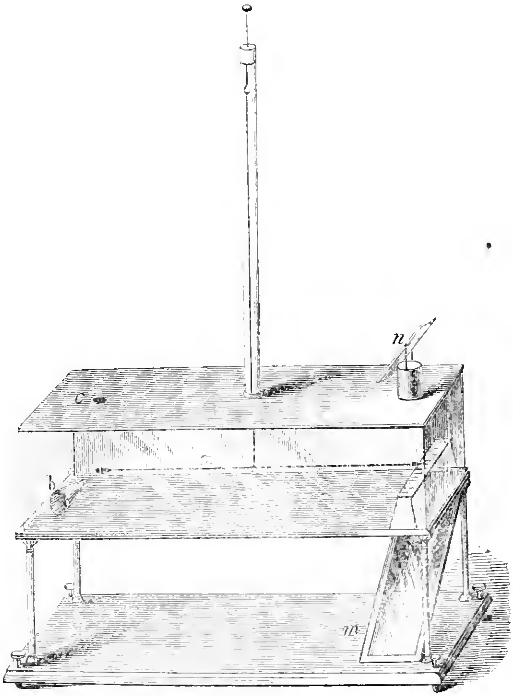
The long and slender glass needle *a*, is suspended by means of a fibre of spun glass, or by two parallel fibres of cocoon silk, within a chamber whose double walls of plate glass, with the intervening air space, protect it from sudden changes of temperature. Upon one end, this needle carries a vertical disk or vane of gilt paper, while the other bears a narrow pointer of the same material. Just beneath the pointer is a glass scale, over which it may move.

To project the motion of this pointer, it is illumined from below, and its image formed as by the well known vertical lantern. For this purpose the needle chamber is mounted upon supports and a mirror *m* placed between it and the base at an angle of 45°. A plano-convex lens is inserted in the bottom of the needle chamber just below the scale-glass, while in a corresponding opening in the top of the chamber is placed a second lens—the objective of the lantern. A parallel beam of light thrown from the lantern upon the mirror *m*, reflected upward through the lenses, and then thrown by the mirror *n*

[1] *Transactions of the Albany Institute*, Vol. viii, p. 181. Journal of the Franklin Institute, Vol. lxvi, p. 343; vol. lxvii, p. 408.

upon the screen, yields a satisfactory image of the scale and pointer, and reveals the slightest motion of the needle.

Few and simple auxiliaries are needed: copper wires and test-tubes are the most important. Copper wires may be cut about six inches long, and each may be thrust through the centre of a flat cork which will serve the two-fold purpose of shielding the wire from the heat of the hand which grasps it, and of supporting it erect in the chamber by resting upon the top, when the wire is thrust through the opening *c*. We can conveniently refer to these as proof wires.



A few experiments selected from those which I am accustomed to make with an instrument of this kind, will indicate the class of illustrations to which it is adapted.

Heat by Chemical Action.—1. Insert a thin test-tube, of such size that while the tube will pass through the opening *c*, the mouth of it will not. and of such length that when inserted it will reach down to a point about an inch below the level of the needle. Wet the end of a proof wire with oil of vitriol, and then touch it with a drop of water. Plunge the wire down into the test-tube immediately, and after a brief interval the needle swings towards the tube in obedience to the heat evolved by the chemical action of the liquids.

The tube forbids the introduction of vapors into the chamber, and prevents any disturbance that might arise therefrom. The chemical action evolves heat, the proof wire receives it, and in turn imparts it to the walls of the tube, by which convection currents are set up in the air outside, wafting the needle vane towards the tube.

2. Into the mouth of the tube insert a small funnel; through this introduce a small quantity of nitric acid and add a clipping of copper. The motion of the needle toward the tube very quickly announces the heat produced in the chemical action of these two substances.

3. Insert another test-tube, and fill it, as in the former experiment, nearly to the level of the needle with plumbic acetate. Add drops of potassic iodide. The precipitate falls at once, and the motion of the needle, in a few seconds, declares the change of temperature in the precipitation.

Heat by Mechanical Action.—1. Remove the test-tube. Let the end of a proof wire be placed upon a surface of metal or of stone, and receive the blow of a hammer or a one-pound weight falling a distance of one foot upon it. Quickly insert the wire through the opening *c*. The needle approaches the wire, announcing the evolution of heat by the blow.

2. Seize another proof wire by its cork, and draw the end of it once between two surfaces of wood gently pressed against it. Immediately insert the wire into the thermoscope, and the needle swings toward it, showing the rise of temperature by friction.

Conduction of Heat.—Bend the upper part of a proof wire at right angles with the lower, and let it be long enough to reach horizontally beyond the edge of the instrument when the lower part is inserted through *c*. Apply the flame of a lamp to the projecting end of the proof wire. In about thirty seconds the needle is in motion toward the lower end of the wire, showing the transmission of heat from the distant end.

Cold by Evaporation.—1. Plunge the end of a proof wire into water, and afterward by exposure to air let the fluid evaporate. Thrust the wire into the chamber, and after a few seconds the needle is in motion away from the wire, indicating reduction of temperature by evaporation.

2. But if the temperature is very considerably reduced, as it may be often by the evaporation of ether instead of water, the needle swings toward the wire. It is because a well defined air current downward is produced by the greater reduction of temperature, and the adjacent parts of the medium are drawn toward the stream, carrying the needle with them.

Radiation of Heat.—Place the flame of an alcohol lamp at a distance of two feet in front of the cone *b*. In about fifteen seconds the needle is in motion toward it.

The rays collected by the cone fall upon the charred paper, which closes the inner end and warms it. The consequent convection current drives the vane.

The hand may be placed in front of the cone, and motion of the needle will ensue after a length of time depending upon the distance of the hand.

Athermancy.—A sheet of glass, a tank of water, of alum, or any other substance, may be interposed between the source of heat and the mouth of the cone. The motion of the needle is prevented according to the athermancy of the screen.

The sensitiveness of the thermoscope depends on the length and lightness of the needle, and the character of its suspension. In the instrument with which the foregoing experiments have been made, the needle is twelve inches in length, and with its attachments weighs about two grains. It is suspended by a very fine fibre of spun glass, eighteen inches long.

Illumined by the lime-light, the needle is, after a time, disturbed by the warmth of the beam itself. To postpone this difficulty, a tank of alum is interposed. The proximity of the hot lantern may also become troublesome when the experiments are continued for a long time, but this difficulty may also be obviated by a suitable screen.

For the best success, the temperature of the instrument should be the same as that of the surrounding atmosphere. It is important, therefore, that the thermoscope, and all the materials to be used with it, should be gathered beforehand and left in position for use long enough to acquire the temperature of the room. If the temperature of the room is slightly *lower* than that of the interior of the instrument, the motion of the needle, for heat, in experiments in radiation, may be *away from the source of heat*, instead of toward it; it will be so, if the degree of heat applied has the proper relation to the difference of temperature between the inside and outside of the instrument.[1] A heat sufficiently strong, however, will bring the needle toward itself in every case.

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[1] This apparent repulsion is not the effect of convection currents; it is due to a molecular transmission of energy from the heated surface outward to the needle-vane by the air at rest,—at rest, because two equal influences are soliciting it in opposite directions at the moment. This phenomenon was first described and explained by the present writer, Oct. 4th, 1875. See *Proceedings of the Poughkeepsie Soc. Nat. Sci.* Vol. i, p. 53.

REMARKS ON HAGEN'S PROOF OF THE METHOD OF LEAST SQUARES.

By MANSFIELD MERRIMAN, Ph. D., Instructor in the Sheffield Scientific School of Yale College.

In 1837 Hagen[i] put forth a new hypothesis or axiom, by which an accidental error of observation was regarded as the result of the combination of a large number of small elementary errors, applied to it the binomial formula, gave a simple method of finding its general term as the number of terms increases without limit, and showed that the negative exponent in the resulting expression was proportional to the square of the error of observation. I apply the words "Hagen's Proof" to all demonstrations of the Method of Least Squares which are based on these fundamental ideas, for to Hagen is due the great credit of having first shown the possibility of thus using them.

Hagen was not the first to show that the coefficient of the general term of the binomial expansion is proportional to the limit e^{-n^2} when the number of terms becomes infinitely great. This was done by Laplace in 1812[ii] and by Poisson in 1830 and 1836,[iii] but they gave no hint of the application of the idea to the theory of errors of observation. Young in 1819[iv] used the binomial formula for the discussion of the probable error of the arithmetical mean, but he does not allude to its connection with the exponential, or attempt to apply it to investigate the problem of Least Squares. To Hagen is due the honor of introducing a new proof, whose fundamental principles and methods are entirely different from any preceding demonstration.

I might quote from many subsequent writers—Quetelet in 1846,[v] Wittstein in 1849,[vi] Encke in 1850,[vii] Price in 1865,[viii] Natani in 1866,[ix]

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i *Grundzüge der Wahrscheinlichkeitsrechnung*, pp. 29–38.

ii *Théorie Analytique des Probabilités*, pp. 296–300.

iii *Mém. Acad. Paris*, Vol. ix, pp. 239–250. *Comptes Rendus*, Vol. ii, pp. 603–613.

iv *Philos. Trans., London*, for 1819, pp. 70–81.

v *Lettres sur la Théorie des Probabilités*, pp. 384–387.

vi *Lehrbuch der Differential- und Integralrechnung*, Vol. ii, pp. 348–354.

vii *Berliner astronomisches Jahrbuch*, for 1853, pp. 330–350.

viii *Infinitesimal Calculus*, Vol. ii, pp. 376–379.

ix *Hoffmann's Mathematisches Wörterbuch*, Vol. v, pp. 16–33.

Faà-de-Bruno in 1869,[i] Meyer in 1874,[ii] Kummell in 1876,[iii]—to show that the method first given by Hagen is the very essence of their demonstrations. No two of these are exactly alike, and each perhaps contains simplifications or improvements upon Hagen's presentation. Each author deserves credit for what he has done, but unless he has given something of more value than Hagen, Hagen's name should be associated with the investigation. Price's discussion was undoubtedly derived from German sources, although not a word of acknowledgment is given. I call it "Hagen's Proof," and consider the modifications as of little historic importance.[iv]

Mr. Kummell, in the last number of this JOURNAL (p. 273), claims that the expression deduced by Hagen,

$$y = \frac{1}{\sqrt{n\pi}} e^{-\frac{x^2}{n}},$$

is an absurd one, since when we substitute for n its value ∞, it reduces to $y = 0$. To which I reply that exactly the same objection, using the same logic, applies to his own expressions on p. 272. He gives

$$y = \sqrt{\frac{2}{m\pi}} e^{-h^2 x^2},$$

and states that "$m = \infty$," hence introducing this value of m, we have

$$y = 0 \,.\, e^{-h^2 x^2} = 0.$$

Nothing is more dangerous in mathematics than the use of the symbols ∞ and 0, without a right comprehension of their meaning. Mr. Kummell's use of these symbols and of the quantity dx is unscientific and inconsistent. dx on p. 271 "is a constant for a particular class of observations, larger for poor observations than for

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i *Traité du Calcul des Erreurs*, pp. 44–45.

ii *Calcul des Probabilités*, p. 215.

iii *The Analyst*, Vol. iii, pp. 133–135.

iv Price did not originate the idea of placing $m\,dx^2$ equal to the reciprocal of h^2. This is due to Wittstein. Mr. Kummell was not the first to place $dx = 2\,\Delta x$: this was done by Dienger in 1852; see *Archiv der Mathematik und Physik*, Vol. xviii. p. 152. In view of all these historical facts, it was rather indiscreet in Mr. Kummell to charge me with borrowing from his *Analyst* article.

good ones;" in the integration on p. 272, it is taken as a variable whose limit is 0 or nothing. Having shown that

$$\text{“}c = \sqrt{\frac{2}{m\,\pi}} \text{ where } m = \infty,\text{”}$$

he regards this value of c as "an absolute constant." The true conception of ∞ and 0 as limits of variables can alone avoid error in their use.[i]

Let y be the probability of the error x, and e the number 2·71828.., then, as shown in my article,

$$y = c\,e^{-h^2 x^2},$$

in which c and h are quantities depending upon the precision of the observations. This is correct, says Mr. Kummell, "if c be excepted, which has nothing at all to do with the precision of the observations," and he offers some inconclusive reasons to show that its value is invariable.

Laplace has said that the Theory of Probability is merely common sense reduced to calculation, and before proceeding to show that Mr. Kummell's reasoning in regard to c is unsound, let us test the question by the instinct of common sense. In the above equation let $x = 0$, then $y = c$; c is hence the probability of committing no error at all. Now does experience declare that the probability of committing no error is entirely independent of the skill of the observer or the precision of the instrument? Suppose that a boy with a pop-gun fires at a target; is it just as probable that the exact centre will be hit as when the skilled marksman of Creedmoor takes aim with his rifle? Is it just as probable that there will be no error in an angle measured with the magnetic compass as when the finely graduated theodolite is used? Common sense refuses to give assent to such propositions, and the Theory of Probability, rightly interpreted, supports the decision of common sense by declaring that c is related to the precision of the measurement.

If Mr. Kummell insists that c is an absolute constant, it devolves on him to deduce its numerical value, but this he is unable to do.

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[i] To use an old illustration, let $n = \textit{infinity}$, then also $2\,n = \textit{infinity}$, hence $n = 2\,n$ or $1 = 2$! On pp. 133–135 of *The Analyst*, Vol. iii, we find $2\,\Omega = \infty$, $2\,\Omega\,i = \infty$ and $\Omega = \infty$. Are these ∞'s all equal?

His value for c is

$$\text{“}c = \sqrt{\frac{2}{m\pi}} \text{ where } m = \infty.\text{”}$$

If we insert in this Mr. Kummell's value for m, we have,

$$c = \sqrt{\frac{2}{\pi}0} = \sqrt{0} = 0.$$

Now are we to conclude from this that the value of c is *nothing?* If c is not *nothing*, what is the constant value which Mr. Kummell claims for it?

The following are the errors which Mr. Kummell's reasoning (on pp. 271–272) contains: 1, that m is an absolute constant; 2, that ∞ and its reciprocal 0 are absolute constants; 3, that dx is a finite quantity which governs the precision of the observations; 4, that it is allowable to eliminate m by separating $m\,dx^2$ into the factors m and dx^2; 5, that the test of integration is, under the above supposition as to dx, sufficient; 6, that in contradiction of this supposition, dx in the integral has a different meaning from the dx in the preceding equations. These errors combine to produce the correct value of c, but the interpretation of the meaning of that value is erroneous.

Let an indefinite horizontal line be drawn, and at some point in it a perpendicular be erected to represent Mr. Kummell's absolute value of c. Let a curve of facility of error be drawn for the two cases,

$$y = c\,e^{-x^2} \quad\text{and}\quad y = c\,e^{-4x^2},$$

and it will be seen that the second curve is entirely enclosed by the first. The sum of all the possible values of y must in each case be unity. But this is impossible, for the area of the second curve is only a portion of the area of the first. This simple geometrical illustration, instead of "obscuring the subject," sets forth clearly the defects of Mr. Kummell's reasoning on the test for the value of c.[1] It is not merely on dx that the precision of the observations depends; it is upon the magnitude of the greatest practical error $m\,\Delta x$, or upon the probabilities of several particular errors.

It will be evident enough by this time, that Gauss, and the many writers who have followed him, are perfectly justified in regarding c

[1] In my *Elements of the Method of Least Squares*, p. 18, a graphical illustration of the precision of two sets of observations of unequal weight is given, supposing c to be proportional to h. This is the common practical case.

as related to the precision of the observations, notwithstanding Mr. Kummell's charges of "hasty assumptions," and "theoretical blunders."

The above replies to Mr. Kummell's fifth and fourth objections, and also shows that his third has no foundation, since his own reason why $(m + 2)\ \Delta x^2 =$ a positive quantity is insufficient and incorrect. In my article it was explained that m is a number, that Δx is the abscissa unit, and that $m\ \Delta x$ is the greatest possible error. The product $(m + 2)\ \Delta x^2$ is accordingly a rectangle, whose base $(m + 2)\ \Delta x$ is indefinitely long, and whose altitude Δx is indefinitely short. As the curve becomes continuous, it hence approaches the limit $\infty . 0$, and for mere convenience we represent it in terms of h, and leave its value to be determined when occasion rises for its use. I frankly confess that my explanation of this and of his second point was not as full as it ought to have been in an elementary discussion, and I acknowledge the typographical error (p. 183, line 9 from bottom); the reading is "Δx is an indefinitely small quantity of the same kind as x." His first charge I deny squarely and emphatically.

The Maiche Battery.—The inventor claims that his battery is energetic, constant with a single liquid, never polarizing, always ready, without change in the points of contact, and using only what is theoretically indispensable. It possesses an electro-motive force three-fourths as great as the Bunsen cell, and deposits a kilogramme of copper at a cost of less than a franc, or nearly an equivalent of copper for an equivalent of zinc. It serves equally well for furnishing powerful currents or currents of long duration.—*Les Mondes.*

C.

Clock Regulation.—In Vienna, clocks of public buildings and offices, stores, hotels, coffee-houses, private dwellings, etc., are now regulated by means of compressed air. The air is conveyed to all parts of the city in tubes, like gas, and a complete uniformity of time is established by a standard regulator.—*Fortsch. d. Zeit.* C.

Kangaroo Leather.—Kangaroo hides have already become an important article of export from Australia. They make the most pliable leather that is known, admirably fitted for boot-legs, gloves, and riding whips. The skins are sent to Europe, some tanned, and some simply dried.—*Fortsch. d. Zeit.* C.

ON MARINE STEAM BOILERS: THEIR DESIGN, CONSTRUCTION, OPERATION, AND WEAR.

By CHAS. H. HASWELL, Esq., Member.

[Read at the Eighteenth Session of the Institution of Naval Architects, at Glasgow, August, 1877: Lord Hampton in the Chair.]

In consequence of the announcement that the reading of Papers "On the Marine Steam Boiler" would be entertained at the Glasgow Meeting of the Institution, I presume to address you; and in so doing it is but just to note that as I did not receive advice of the meeting until the 28th of June, I am consequently not only restricted to a very brief period of consideration of the subject, but am precluded from furnishing illustrations, in order that my communication should be received on or before July 24th, as required; and in a treatise on a subject so prolific in elements of consideration, the necessary short period assigned for its reading confines me to that design and construction of boiler which, in my opinion, is the most effective in operation, economic in volume, weight, and cost, and enduring in operation. In submitting the following, I assume that the deductions of my own experience, observations and study, are asked for in brief and acceptable form, and not a republication of the observations of others, or tables of results, involving time and study to eliminate them for practical application; and with this view of your requirements and my position I submit:—Of the several designs of boilers in general and accepted use for marine service, there are the over-head return; multi-fire tubular, with a steam chimney, as in the European marine; the cylindrical shell and furnace, with a combination of lateral and over-head return fire tubes, without a steam chimney; and the horizontal, or vertical direct multi-fire tubular, as applied in small vessels, tugs, and launches; the latter (vertical direct) being only resorted to in exceptional cases, as when the construction and requirements of the vessel are dominant to economy of cost, space, and effect; and these are the only designs that I purpose to consider, as most others are but modifications of them in one or more of their features, or of a design unworthy of reference, inasmuch as they cannot successfully compete with them in a combination of the elements necessary to the requirements of either the Commercial or Naval Marine, and

for the following causes:—The water tubes or cells, whatever their course or shape, where salt water or aught but exceptionally pure water is used, are not to be considered, in consequence of the coating of their inner surface with scale, and its arrest of communication of the heat, combined with the difficulty of removing it, added to the further difficulty of removing the ashes and soot from between the tubes. The drop flue is objectionable from the difficulty of washing or scaling the intermediate spaces between the flues, the delay in raising steam, its great proportionate length, and the exposure of the crown of its furnace to low water, and the necessity of an increased proportion both in diameter and height of smoke-pipe, for equal intensity of combustion, notwithstanding the effective application of its heat. A flue boiler, or one in which the internal passages beyond the bridge wall are wholly of a diameter exceeding that assigned to tubes, involves too great a volume and weight of boiler and water, without equivalent compensating advantages. All other accepted designs and forms, whatever their conformations or alleged differences and advantages, are but modifications of the type of boiler known as the multi-fire tubular return or direct, that is, a combination of furnace bridge, combustion chamber and tubes; the forms and proportions of each being progressively attained by the experience and observations of a host of laborers who have either preceded us, or are yet fellow workmen in the field of mechanical and physical development. Thus the dry bridge and combustion chamber are those of Wright in 1756, Dewrance in 1845, and Baker in 1846. The dead plate, that of Watt in 1785. The water bridge is that of Crampton in 1842, and Mills in 1851, and the air bridge, that of Slater in 1831. The horizontal fire tube is that of Bolton, of 1780, modified by Ericsson in 1828, Seguin and Booth in 1829, by the Hawthornes in 1839, and by Glasson in 1852. The vertical fire tube is that of Rumsey in 1788. The water bottom is that of Allen in 1730, and of Fraser in 1827. The vertical water spaces, or legs, are those of Stephens and Hardley in 1748, Napier in 1842, and Dundonald in 1843. The steam drum or dome is that of Stevens in 1803. The superheating of the steam is the design of Hateley in 1768, English in 1809, and of Allaire, with his steam chimney, in 1827. The hanging bridge is that of Johnson in 1818, and the cylindrical boiler with return flues, that of the Napiers in 1831. The introduction of air in the combustion chamber and over the fire in the furnace is the design of Thompson

in 1796, the Robertsons in 1800, Arnott in 1821, and Williams in 1839, and finally, the general design of a marine boiler is that of Symington in 1812. Assuming then, that the boiler best adapted and most effective for the marine service is the multi-fire tubular return, I further submit my views of its design, construction, etc.

Design.—In the matter of design, the first element of consideration is its conformation, which is second only to its service, whether for a merchant or naval vessel; the first, unless an extreme of steam pressure is required, admitting of an exclusively over-head return; whilst the latter, from the restrictions of the shell to the least practicable dimensions as a cylinder, would seem to render a resort to lateral return tubes indispensable, in order to obtain the necessary proportion of transverse area. When the limit of dimensions of the shell is arrived at, the necessary area of grate, and the consequent volume of furnace, combustion chamber, calorimeter, or transverse area of tubes, and of smoke-pipe, are next to be considered.

Grates.—As every practicable facility should be given to the admission of air, the inter- or air-spaces should be as wide and as frequent as practicable.

Furnace.—The volume of it should be fully sufficient to admit of the necessary combination of the products of combustion and of atmospheric air, and when it is considered that the proportion of water vaporized by the furnace surface, compared with that of the tubes, is very nearly one-half of the whole, the propriety of giving it the greatest practicable limit will be readily recognized. The volume of surplus air entering the furnace, or the amount over that chemically consumed in the combustion of the fuel, is less as the rate of combustion is increased; and at a rate of 18 pounds per square foot of grate per hour, the volume may range from 35 to 50 cubic feet per pound of coal. That short furnaces are more effective than long ones, and that the coking of the coal gives an appreciable advantage.

Bridge—The bridge is more exposed to heat than any other part of the absorbing surface, and, as a consequence, the current of water induced, when it is a water bridge, is correspondingly greater; thereby the circulation of the water is increased and a more effective operation, with economy of fuel, is attained; thus rendering the adoption of a water bridge preferable to a dry one, even allowing for the reduction of the temperature of combustion at that point consequent upon the portion absorbed by the water. The area of the opening

over the bridge or calorimeter, should be somewhat less than that of the tubes, the proportion being defined by the quantity of coal consumed per hour, and by the intensity of the draught of the furnace.

Combustion Chamber.—When the furnace is restricted in volume, a combustion, or flame chamber, an intervening space between the bridge or terminus of the furnace proper and the face of the tubes, becomes indispensable to admit of the proper admixture of the products of combustion.

Ash-Pit.—Inasmuch as there are from 140 to 150 cubic feet of air at 62° Fahr. theoretically required for the combustion of a pound of coal of average quality, the area of the ash-pit opening should be equal to the admission of this volume, added to the surplus volume consequent upon the combustion, which is inversely as the rate thereof, the velocity of current due to the height of the smoke-pipe being duly considered. Entertaining these views as to the general features and requirements of a marine boiler, and aided by the deductions and observations of experience and experiment, I assume the following: 1st. The greater the area of grate, in a boiler of proper proportions, the less is the evaporation of water at like rates of fuel; and the same area of heating surface. That is, the combustion of the fuel and the absorption of the heat by the water are not as effective. 2d. The evaporation of water in a boiler is not directly as the fuel consumed. That is, the water does not receive heat in direct proportion to the fuel consumed, and a greater proportion of the heat escapes at the terminus of the tubes. 3d. The evaporation from the furnace is from two-thirds to one-half of that from the whole heating surface, according to the conformation and proportions of the boiler. That is, the direct effect of the fire is far in excess of that derived from the radiation of its heat. 4th. That evaporation, beyond the direct effect of the fire in the furnace, from equal lengths of continuous fire tubes, decreases in a geometrical proportion. That is, that with equal lengths and surfaces of tubes, the water evaporated therefrom will decrease one-half in effect for each length. 5th. That the combustion of coal can be made more effective and economical by the partial coking of it upon the dead plate at the furnace door, and also by the admission of air in proper volume, and at proper periods, at the furnace door, at the bridge, and in the combustion chamber. 6th. That in a boiler properly designed and constructed, which conditions include material, riveting and bracing, there is no neces-

sity of proving much beyond their limit of maximum working stress, for it cannot under any normal operation be submitted to any greater stress, and an abnormal condition it is impracticable to provide for. Lastly. That foaming (priming) involves not only a waste of heat, but an uncertainty in the level of the water, that frequently necessitates the arrest of operation of the boiler, and is often the cause of its being burned, and sometimes of its disruption. Reviewing, then, these elements, I submit the following rules for the proportions and construction of a marine steam boiler, with multi-fire tubular return:

CONSTRUCTION.

For a Combustion of 16 *pounds of Bituminous Coal per Square Foot of Grate per hour, with a depth upon the grates, not exceeding* 9 *inches; heating surface* 6 *times the area of the grates, and with fresh water.* (When salt water is used, one-twelfth is to be added to the surface.)

Volume of Water from and at 212°.

$10\ C + 25 = V$, and by inversion $\frac{V - 25}{10} = C$, C representing the coal in pounds per square foot of grate per hour, and V the volume of water vaporized in pounds.

For a like Combustion of Coal, and heating surface 50 *times the area of the grate.*

$$11{\cdot}2\ C + 25 = V \text{ and } \frac{V - 25}{11{\cdot}2} = C.$$

For a Combustion of 30 *pounds of Bituminous Coal per Square Foot of Grate per hour, with a depth upon the grates of* 12 *inches, heating surface* 36 *times the area of the grate, and with fresh water.*

Volume of Water from and at 212°.

$$9{\cdot}8\ C + 25 = V \text{ and } \frac{V - 25}{9{\cdot}8} = C.$$

For a like Combustion of Coal, and heating surface 50 *times the area of the grate.*

$$10{\cdot}9\ C + 25 = V \text{ and } \frac{V - 25}{10{\cdot}9} = C.$$

When the evaporation is from a temperature of feed-water less than 212°, and at a pressure of steam exceeding that due to a like temperature of 212° as above given, the additional capacity of the

boiler is determined by the formula $\frac{H + 32° - t}{966}$ = proportional increase—H representing the total heat of the steam at the pressure required, and t the temperature of the feed-water. *Illustration.*—If the proportionate increase for a pressure of steam of 60 pounds per square inch (mercurial gauge), and a temperature of feed-water of 60° is required, then $\frac{1175° + 32° - 60°}{966} = 1{\cdot}187$, and inversely, if an equivalent evaporation from and at 212° as preceding, when the pressure of the steam and the temperature of the feed-water are given.

Grates.—These should be made as thin as practicable with the stress to which they are to be subjected, in order to obtain the greatest area of air-spaces, which range from $\frac{1}{2}$ to $\frac{13}{16}$ of an inch, according to the condition of the coal used; and, although it may be very convenient to divide the extreme length of the grate into two or three lengths, their bearers and dead ends objectionably reduce both the current of air under and through the spaces; and they should be set at a depressed inclination to the bridge.

Furnace.—The volume of it, above the grates, to admit of the ready combustion of the atmospheric air and the products of the fuel, should be from 2·75 to 3 cubic feet per square foot of grate, and where the volume is restricted to a less proportion than this, a combustion chamber over and beyond the bridge is imperative. It should also be enclosed with a water bottom.

Ash-Pit.—The transverse area of it should be one-fourth the area of the grate surface.

Bridge.—Its transverse area, or calorimeter, may be reduced to from seven to eight-tenths of the area of the lower flues or of the tubes.

Tubes.—Their transverse area, when the boiler is to be located in the hold of a vessel, cannot be determined by any fixed rule, for the evident reason, that in a great majority of cases, the transverse area in which they are to be set, is controlled by particular circumstances, as in length, width, and height, and consequently to admit of the necessary water and steam spaces, the proper area may not be attainable without a sacrifice of surface, and contrariwise; as the area of a tube increases as the square of its diameter, and the surface only as the diameter, large tubes, whilst affording the area, might be deficient in surface, and small ones, whilst affording the surface, would

be deficient in area. When height of a boiler can be had greater than the width, a section approaching a vertical ellipse can be resorted to, and the required area attained. When practicable, the area of the tubes should be fully 30 square inches for each square foot of grate surface, their length proportionate to the intensity of the combustion and draught, and their inclination upwards to the chimney. In general, their length within the range of 1 and 4 inches in diameter should be from 30 to 36 inches for each inch of internal diameter.

Smoke-Pipe and Connections.—Their area should somewhat exceed that of the terminus of the tubes, in order to compensate for the right-angled flexure of the draught current, the excess being regulated by the height of the pipe, and the temperature of the products at its base.

Shell and Furnace Plates.—With the results of the experiments of Fairbairn, Johnson, and others, added to those deduced from an extended practice, the necessary thickness of metal in a boiler, the diameter and number of rivets, the areas of staying, etc., are readily computed with a proper factor or unit for safe resistance; but inasmuch as there are very varying elements comprised in the construction of a boiler, a general assumption of tensile resistance of the plates and rods, and a uniform factor of safety, are not practicable to meet the demands of the high pressure of steam of the present day, and the exactness of economy of material, that the character of the profession renders necessary. Thus, the iron varies not only in strength in different localities and manufactures, but is inherently of different grades, and it is to be considered:—Whether the boiler is to be operated with fresh or salt water, or it is to be located under a second deck, and its lower surfaces to be exposed to the wash of bilge water, or moisture arising from wet coals, or whether the surfaces are to be regular as plain cylinders. If exposed to oxidation, a crystallized iron of the requisite tensile resistance is better adapted for wear than iron of a fibrous structure. In determining the factor of safety, then, reference should be had first to the quality of the material, its degree of elasticity, and then to what margin of deduction should be taken for the incidents of manufacture, the service to which it is to be exposed, and its wear. As a general rule, a factor of 6 will be fully sufficient, and with a homogeneous iron of a high degree of elasticity, and for a boiler that will be properly cared for, a factor of 5 will be as ample as one of 7 in many different and oft occurring

cases. I submit, however, that the thickness of the plates can be more justly computed after their tensile resistance has been determined, by deducting therefrom the loss due to the character of the riveting, viz., three-tenths for double riveting, and five-tenths for single, and then dividing by a common factor of safety, whereby the thickness of the plate would be determined proportionate to its actual strength. Where salt water is to be used it is proper to add one-sixth to the thickness of the plate. When practicable, therefore, it will be very advantageous to know the exact tensile resistance of the plates, in preference to assuming a mean or general value. Thus, wrought iron boiler plates range in resistance from 48,000 to 62,000 pounds per square inch, the mean being 55,000; hence, if the plates to be used were of a value of 62,000, and the mean were taken, the excess of weight and metal in an ordinary marine boiler of 100 nominal horse power, would be 4980 pounds for the same strength of its plates; and contrariwise, if the plates are below the mean, the computation should be made in accordance therewith. The thickness of the plates of a cylindrical boiler, or combustion chamber, or flue, is computed as follows:—

For Single Riveting.

$$\tfrac{1}{2} \times \frac{D \times P \times 2}{R \div 3} = \text{thickness.}$$

For Double Riveting.

$$\tfrac{1}{2} \times \frac{D \times P \times 1{\cdot}75}{R \div 3} = \text{thickness.}$$

D representing the diameter in inches, and R the tensile resistance of the plates in pounds.

Stayed Plates or Flat Surfaces.—By experiment it has been determined that a stay bolt $\frac{3}{4}$ inch in diameter at the base of its thread, screwed and riveted into a wrought iron plate $\frac{3}{8}$ inch in thickness, will draw, at an average pressure of 24,000 pounds upon an area of 20 square inches, and that the plate will perceptibly bulge at a pressure of 500 pounds upon a like area. Hence, using 4·5 as a factor of safety (riveting does not enter into the computation), the thickness is thus determined:—

$$\frac{P \times d^2}{15500} = \text{thickness.}$$

P representing the pressure in pounds per square inch, and d the distance between the centres of contiguous bolts or stays, or area of the surface.

Thus $500 \div 4{\cdot}5 = 111$ and $\sqrt{\dfrac{111 \times 20}{15500}} = {\cdot}378$ inch in thickness, for a bolt $\frac{3}{4}$ inch in diameter at base of thread, and $\sqrt{\dfrac{111 \times 9^2}{15500}} = {\cdot}76$ inch in thickness.

Bolts and Stays.—For the diameter of bolts and the area of stays, the following formulæ will give the necessary dimensions:—

Bolts.—$d\sqrt{\dfrac{P}{R \div 10}}$ = diameter of body of bolt, d representing the distance between centres of the bolts, P the pressure in pounds per square inch, and R the tensile strength of the metal. When screwed as well as riveted, the difference in their resistance is not sufficiently increased to authorize a material reduction of the above factor, but when screwed, the diameter must be taken at the base of the thread. The diameter of the body of a stay bolt should bear a just proportion to the thickness of the plate, say from 2 to $2\frac{1}{8}$ times the thickness of it.

Stays.—$\dfrac{A \times P}{R \div 8}$ = area of section, A representing area of surface. The increase of the factor in this case is in order to compensate for the decrease of strength of the stay in welding and bending.

Diagonal Stays.—$\dfrac{P}{\text{Cosine } L}$ = tension on stay, L representing the angle of the stay and the line of pressure. Hence, $\dfrac{\text{Tension}}{R \div 8}$ = area of section, and when salt water is to be used, add one-sixth to the area of the bolt or stay, as for plates.

Marine Vertical Fire-tubular Boiler. For a Combustion of 10 *pounds of Bituminous Coal per square foot of grate per hour, heating surface* 30 *times the area of the grate, and with fresh water.*

Volume of Water from and at 212°.

$$7{\cdot}2 \times 8{\cdot}6\ C = V.$$

For a Combustion of 20 *pounds of like Coal, and with like proportion of heating surface, etc.*

$$7 + 8{\cdot}6\ C = V.$$

For a combustion of 10 *and* 20 *pounds of like Coal, and with a heating surface of* 50 *times the area of the grate.*

$$20 + 8{\cdot}6\ C = V.$$

When salt water is used one-twelfth is to be added to the surface. Grates, furnace, bridge, tubes, plates, smoke-pipes, ash-pit, and steam-room, should assimilate to the proportions given for a horizontal return boiler as near as practicable, consistent with the difference in design.

Blowing off.—Where salt water is used it becomes necessary to blow or pump out the saturated water and matter in suspension, and this operation is rendered the most effective, and consequently the least expensive of heat, by blowing from the surface over the part where there is the greatest ebullition, and also from the bottom where the water is the most quiescent, and consequently it is the most dense; and in blowing, the operation should be very brief, otherwise a current will be induced that will extend to water other than that proper to be removed.

Foaming.—The prevention of foaming (priming), requires not only a just proportionate volume of steam space in a boiler to that of the steam space in the cylinder and the number of strokes of the piston, but that the width of the water level over the furnace should be equal, if not superior, to that of the grate, in order that the ascending current of water from the sides of the furnace may not be so contracted at the water line as to involve a violent ebullition, and also that the entire water level should be proportionate to the intensity of the combustion and the revolutions of the attached engine. It is very difficult to assign a proportionate volume of steam-room to meet all cases, in consequence of the many and varying elements in connection with the operation that induce foaming. As a general rule, however, it should be, whenever it is practicable of attainment, from four to five times the volume in cubic feet of the area of the grate in square feet. The presence of an external cylinder for the attachment of the steam and water gauges in order that the level of the water may be ascertained, is an exponent of a proportion of boiler that is not only not creditable to the profession, but is, in fact, a step backwards.

Auxiliaries.—The auxiliaries to the operation of a boiler are feed-water heating, superheating the steam, blast draught, and blow-off.

Feed-water Heating or "Economizer."—Feed-water can be raised above the temperature of its delivery from its pump, only at the expense of the heat of evaporation of the water in the boiler, unless it is heated external thereto, as at the base of the smoke-pipe, or as in a water door to the front connection. The circumstance that a coil of feed pipes may be placed in the combustion chamber or back connection of a boiler with economy of evaporation, proves only that the heat of its combustion was not fully absorbed for want of water surface, either from an insufficiency of it, or the existence of an undue velocity of draught. If the heat of a boiler is fully utilized by its proper surface, it cannot be absorbed more effectually, and if its flues and connections are justly proportioned they will not admit the accommodation of a coil of pipes, inasmuch as the extension of the connections of a boiler to accommodate them involves length, weight, and cost, without adequate compensation.

Superheating.—Although the superheating of the steam is productive of increased effect with equal consumption of fuel, all that is required can be readily obtained in a steam chimney, without the introduction of any separate instrument or arrangement of pipes. In 1828, when James P. Allaire invented and introduced this chimney, the cylinder pistons were packed with hemp gaskets, and the voids of the disc of the piston were filled with a light wood, in order to exclude water of condensation, and upon the very first essay with the chimney the steam was so superheated that it destroyed the hemp gaskets and charred the wood in the pistons.

Steam Jet or Blast Draught.—The expenditure of the steam to maintain a steam jet, or a blast draught in any manner, in a boiler of proper proportions, is greater than the increase in the pressure of the steam, and consequent economy. Its utility therefore is confined to an increase of steam, when its acquisition is held to be superior to the economy of its cost.

Scale or Sediment Preventer or Solvents.—There are several kinds of material in use designed for introduction in a boiler to arrest the induration of the deposits from impure or salt water, and all appear to be equally indorsed. In my experience some of these materials, if judiciously introduced, both as to time and quantity, will effect the purpose that is claimed for them.

Effect of Scale.—When the loss of evaporation of water consequent upon the presence of scale in a boiler is justly considered, it will be found preferable to blow off the saturated water so freely as to preclude its deposit, inasmuch as the heat that will be lost by an excess of blowing is less than that lost by the non-conduction of it through the scale.

GENERAL NOTES.

For use in salt water the thickness of plates and the diameter and area of bolts and stays should be increased one-sixth. Wrought iron bolts and stays are reduced in strength by the following operations:—

Cutting the thread of bolts,	25 per cent.
Welding,	20 "
Exposure to sudden strain,	18 "

The mean tensile resistance of boiler plates is 55,000 lbs. per square inch, and with the fibre it is from 8 to 10 per cent. greater than across it. Rivet iron at a temperature of 60° should have a tensile resistance of 60,000 lbs. per square inch. The tensile resistance of steel varies so materially that a computation of its resistance must be made for the particular article. As an exponent, however, the following table of the strength of plates of several manufactures is submitted:

From $\frac{1}{8}$ to $\frac{5}{16}$ of an inch.

	lbs.
Cast steel, $\frac{1}{4}$ and $\frac{3}{16}$,	95,200
Ditto $\frac{1}{4}$,	75,600
Puddled, $\frac{1}{8}$ and $\frac{3}{16}$,	102,600
Ditto	85,000
Ditto	71,700
Fagersta,	59,100
Siemens,	69,900
Fluid compressed,	89,600

The resistance of riveted steel plates with the holes drilled is from 18 to 25 per cent. greater than when punched, depending upon the temper of the metal. The intensity of the draught of a smoke-pipe, is as the square root of its height. In the metal lining of a chimney room, the laps of the plates should lead upwards in order to shield sparks ascending from entering under the plates, and not downwards, as they are invariably set, as if they were to shed water falling from above.

THE FLOW OF WATER THROUGH AN OPENING IN A PIERCED PLATE.

By ROBERT BRIGGS, C. E.[1]

[Read before the American Philosophical Society, August 17th, 1877.]

In the JOURNAL OF THE FRANKLIN INSTITUTE, 3d Series, Vol. 73, page 123, will be found a hypothesis of the origin of the form of the *vena contracta* under certain conditions stated in the paper then published. It was shown that on the assumption that the efflux occurred from the layer or stratum of water under greatest pressure of water column, at the maximum velocity due to that column, the least section of the *vena contracta* would have half the area of the opening of efflux, provided the effect of frictional adhesion of the water to the bottom of the vessel, and the effect of the internal friction or viscosity of the water, were not considered. And it was noticed that the effect from these causes *tended* to enlarge the least section of the vein and increase the quantity of effluent water.

Referring to the words of the paper: "If, however, there is admitted to exist a certain adhesion to the bottom of the vessel or to the surface, or

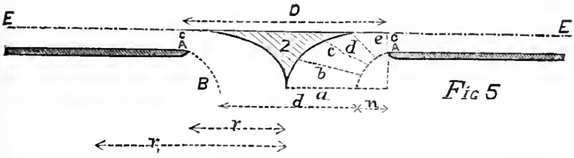

Fig 5

the edges A A, so that the velocity of a particle on A B is less than that fully due to the head; the surface (d) would then become larger than $\frac{1}{2}$ D, the dimension C A would be properly increased to give a corresponding area of efflux, and the conoid Z would also have such contour as would permit the uniformity of flow of each and every particle of the liquid at unchanged velocity, in any section of the *vena contracta* transverse to the flow. This increase of dimension of the cross-section d, and the effect of the descending pencil in accelerating the flow through it, can be taken as sufficient to account for Weisbach's observed value of $d = 0{\cdot}8\ D$, and the position of the plane of least section will be found at about $\frac{1}{4}$ D below the orifice, as has been before quoted."

[1] From the *Trans. Am. Philos. Soc.*

A further illustration of this subject can be instituted by accepting the observed value of the least section of *vena contracta*, which is found to be 0·64 D in place of the hypothetical one of $\frac{1}{2}$ D, and by deducing the form of the effluent vein backwards to the strata of water under greatest pressure. Thus, let it be supposed that Fig. 6 represents (as in Fig. 5) an opening in a thin plate, guarded or protected by a disc Z, of such contour, and so placed that a current flowing towards the opening shall obtain the maximum velocity due to the head, and be diverted from its horizontal to the vertical direction without change of velocity of any particle of the current.

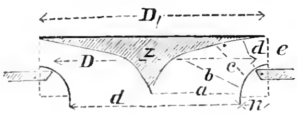

Fig. 6

The contour of the *vena contracta* from the edge of the aperture to the plane of least section is taken to be an arc of a circle—the internal surface of a segment of a ring. Let D be the diameter of the opening in the plate. Suppose d, the diameter of the least section of the *vena contracta*, to have the value given by observation, $d = 0·8\,D$. Then following the previous conditions of form of the conoid Z, we have, the diameter of the disc $= D_1 = 1·13137\,D$, and the radius of the arc of contour $= n = 0·16569\,D$. It will now be observed that the line of the arc of contour, if it is continued within the opening to supposed point of horizontal efflux—the circle of periphery of the disc, gives a stratum of water f (shown more distinctly in Fig. 7), which is cut off from the effluent stream. This stratum has its greatest thickness of $f = 0·01358\,D$. These suppositions place the plane of least section $= 0·152\,D$ below the opening.

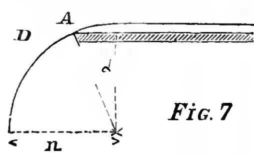

Fig. 7

In Fig. 8 will be seen a similar delineation of the contour of the *vena contracta*, and the lines of the current of maximum constant velocity, as modified by placing the plane of least section at its observed position, or 0·25 D, below the opening in the plate. The contour of the *vena contracta* is here depicted as an arc of an ellipsis which has 0·166 D for its minor radius, and 0·275 D, nearly, for its major one, which will approximate closely to the true

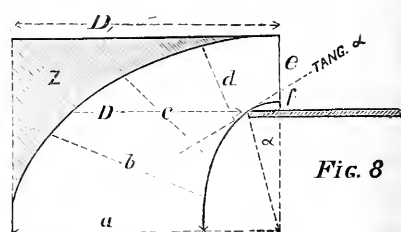

Fig. 8

parabolic form as suggested in the first paper. The thickness of the film or stratum f, which represents the resistance arising from friction of water against the bottom and at *the edge* of the aperture, now becomes about $0{\cdot}025\,D$. The angle α, which the current makes with the edge of the aperture, becomes about 35°.

If these suppositions are correct, a re-entering mouthpiece, shaped to conform to the upper part of the elliptical arc, would give the same contour and sections to the *vena contracta* as that now found to proceed from free discharge at a plain aperture. It would seem also, from the tenor of this discussion, that by substituting a re-entering curve at A, Fig. 7, making the bottom of the vessel to conform to a reversal of the curve $A\,f$, giving the *reversed* elliptical arc α, at the edge of the orifice, so that the tangent of the curvature upwards at the edge should be about 35°, we should then obtain the theoretic least section from a frictionless horizontal surface of = half the area of the opening; and that such a form would be equally effective with the re-entering tube of Mr. Froude, in giving the current at the edge of the aperture its horizontal direction of least resistance, accompanied by the greatest liquid pressure.

THE DEVIATING FORCES OF AN UNSYMMETRICALLY BALANCED FLY-WHEEL.

By Robert Briggs, C. E.[1]

[Read before the American Philosophical Society, August 17th, 1877.]

In the text-books of applied or practical Mechanics—Morin, Rankine, Weisbach, Fairbairn or others—it does not appear that any proper consideration has been given to the strains on the axis of a fly-wheel, which, correctly balanced with regard to the gravity of its masses, and also in the plane of rotation, yet without symmetry of position or mass of the balanced parts, is then accelerated or retarded to meet the usual requirements of a regulator of power. The fact that a fly-wheel must be balanced in one plane to run without vibratory effect at any given speed, and that, when thus balanced, the centrifugal forces of the parts will be in equilibrium and the axis

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[1] From the *Trans. Am. Philos. Soc.*

permanent, is fully stated by all recent writers; but the condition of permanency of axis, when an unsymmetrically balanced fly-wheel gives out or absorbs force, has not been discussed.

The following elementary case shows the proposition distinctly: Let it be supposed that a fly-wheel is formed of a pair of unequal weights at the extremities of arms (radii) of such length as will place the axis in the centre of gravity of the system, thus:

$$\begin{array}{cc|cc} M & & & m \\ O & \text{——} & \text{————} & o \\ V & r & \text{R} & v \end{array}$$

where $M\,m =$ the masses and r R $=$ the radii. Let V_1, V_2, and v_1, v_2 represent the two velocities. The admitted energy from the change of velocities of the masses is thus expressed by the equation:

$$F = [M\,(V_1^2 - V_2^2) + m\,(v_1^2 - v_2^2)] \div 2g. \tag{1}$$

But from the condition of balancing

$$m = M\frac{r}{\text{R}};\ v_1 = V_1\,\frac{\text{R}}{r};\ \text{and } v_2 = V_2\frac{\text{R}}{r}.$$

$$\therefore\ F = \Big[M\,(V_1^2 - V_2^2) + M\,\frac{r}{\text{R}}\big[\,V_1^2\left(\frac{\text{R}}{r}\right)^2 + V_2^2\left(\frac{\text{R}}{r}\right)^2\big]\Big] \div 2g. \tag{2}$$

$$F = M\Big[(1 + \frac{\text{R}}{r}\,(V_1^2 - V_2^2)\Big] \div 2g. \tag{3}$$

Showing that the ratio of force given out by the two halves of the fly-wheels, under any change of velocity, during any instant of time, will be unity, and the axis be in equilibrium, when $1 = R \div r$, and in no other case, and the masses and velocities become equal in the same case.

This condition of unsymmetrical balancing of fly-wheels is by no means an unusual one. The castings of fly-wheels of steam engines, and more especially of pulleys for transmission of force which act generally more or less as fly-wheels, are rarely of such uniformity as not to require balancing—nearly always done on the rim of the wheel, regardless of point of inequality, which is more frequently in the arms than in the rim.

Perhaps the most striking instance is the case of the vertical blowing engine, where the whole weight of the pistons, crossheads and rods rests upon crank-pins inserted in the arms of two fly-wheels at points from one-fourth to one-third the radii of the rim, which weight is counteracted by a suitable load at the rim opposite the

crank-pins. It is then found that much less load is needed to give comparative steadiness of motion than would be required to balance the parts, and that the blowing engine must be balanced to run at a given speed, and thus be liable to definite changes of motion of the fly-wheel each stroke. In all steam engines with single cylinders it must be recognized that during an instant of the stroke, the fly-wheel must, solely and unaided, maintain the speed and give out the whole power of the engine *by retardation*, while in most engines, during a considerable portion of the stroke, the fly-wheel is aiding, or assisting to impel, the shaft of transmission; of course receiving a corresponding impulse from other portions of the same stroke.

The unbalanced forces which result from changes of speed of rotation of these unsymmetrical wheels, are transformed into pressures at the axes, and have to be sustained by the bearings and resisted by the frameworks which carry or support the same, in addition to any strain, proceeding from the mechanism employed in giving rotation or in transmission of power. As pressure or load upon the bearings, the increment of heat derived from friction may cause the total heat to surpass the limit of dispersion in cases where the direct weights of the fly-wheel approach, as they frequently do, the maximum load of practical endurance on the bearing surfaces. The apparently unaccountable heating of some fly-wheel bearings, where the absolute pressures from load or work are not so great as to cause heating, has been noticed by all practical mechanics, and the considerations now presented offer a reasonable hypothesis in explanation.

In Mahan's Moseley's Mechanics will be found some mathematical investigations leading in this direction, see appendix notes D and E, but a study of these forces and an application of the theorem to the special case of a fly-wheel regulating force or power, are needed to complete the theory of practical mechanical construction.

New Electric Lamp.—By the use of circular oblique theophores, with a special clockwork for each, E. Requier has succeeded in making an electric lamp which will operate for 24 hours. He thinks that the instantaneous obedience of the automatic theophore to its solenoid will enable him to divide a sufficiently intense electric current so as to supply a large number of his lamps.—*C. R.* C.

MUSIC OF THE MOONS.

By Pliny Earle Chase, LL. D.

A recent note from Professor Hall, the discoverer of the satellites of Mars, contains the following query:

"Will the inner moon of Mars fall into harmony, or will it make a discord?"

If we start from a point near the theoretical beginning of nebular condensation for the outer satellite,[i] and take $2 \times 3 - 1$ harmonic divisors, of the form $\text{div.}_{n+1} = 3\ \text{div.}_n - \text{div.}_1 = \text{div.}_n + 3^{n-1}$, we find the following accordances:

Numerator.	Divisors.	Quotients.	Observed.
13·7	$d_1 = 1$	13·700	13·692 = Nebular radius.
	$d_2 = 3\,d_1 - d_1 = 2$	6·850	6·846 = Deimus.[ii]
	$d_3 = 3\,d_2 - d_1 = 5$	2·740	2·730 = Phobus.[ii]
	$d_4 = 3\,d_3 - d_1 = 14$	·979	1·000 = ♂ semi-diam.
	$d_5 = 3\,d_4 - d_1 = 41$	·334	·333 = ♂ c. of rad. osc.

In a letter to the editors of the *American Journal of Science and Arts* (Oct., 1877, p. 327), Professor Kirkwood calls attention to the rapid motion of the inner satellite, and asks: "How is this remarkable fact to be reconciled with the cosmogony of Laplace?" He suggests a partial explanation, based upon the motions of Saturn's ring, and concludes with the remark: "Unless some such explanation as this can be given, the short period of the inner satellite will doubtless be regarded as a conclusive argument against the nebular hypothesis."

This is undoubtedly true, if we accept the nebular hypothesis in the form in which it is popularly taught, and in which Laplace is commonly supposed to have held it. But there are probably very few among the students who have given the subject much careful attention, who have supposed that all the planet-building has taken place at the "limit of possible atmosphere," or the point of equal centripetal and centrifugal force. It may well be doubted whether the illustrious French astronomer ever held such an opinion, and it is certain

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[i] *Phil. Mag.*, Oct., 1877, p. 292.

[ii] These are the names proposed for the satellites by their discoverer, Prof. Asaph Hall.

that Sir William Herschel never did, for he speculated on the "gradual subsidence and condensation" of nebulous matter "by the effect of its own gravity, into more or less regular spherical or spheroidal forms, denser (as they must in that case be) towards the centre."[i]

As necessary consequences of such subsidence, there would be an acceleration of velocity in all the nebular particles, the acceleration being more rapid in the nucleus, than near the outer surface of the nebula. Many indications point to the simultaneous, or nearly simultaneous, initiation of numerous planetary centres, and it is very doubtful if either of the two-planet belts, except, perhaps, that of Neptune and Uranus, will be long regarded as having been "thrown off" by the mere increase of centrifugal velocity.

At the very outset of my own investigations,[ii] I was careful to limit my acceptance of the nebular hypothesis to the qualified exposition of the Herschels. "Neither is there any variety of aspect which nebulæ offer, which stands at all in contradiction to this view. Even though we should feel ourselves compelled to reject the idea of a gaseous or vaporous 'nebulous matter,' it loses little or none of its force. Subsidence, and the central aggregation consequent on subsidence, may go on quite as well among a multitude of discrete bodies, under the influence of mutual attraction, and feeble or partially opposing projectile motions, as among the particles of a gaseous fluid."[iii]

It matters not whether there is such a thing as a luminiferous æther, or whether the hypothesis of such an entity is merely a convenient assumption for the co-ordination of results which are due to the action of forces *such as would exist* in such a medium. The proper study of the forces, and of their mathematical consequences, is the great thing to be sought, and the numerous accordances which I have already found, show how prolific such studies may become. Those accordances, as it seems to me, are already sufficient to establish the Herschelian hypothesis as a true theory, beyond the reach of all possible controversy. That the elastic, or quasi-elastic, forces, which are continually operating throughout the solar system, should extend the harmonic laws to the satellites, as well as to the planets

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i Herschel's "Outlines of Astronomy," § 871.

ii *Phil. Mag.*, April, 1876.

iii *Loc. cit.*

and to the spectral lines, is a necessary consequence of the simplicity and unity of design which underlie the manifold phenomena of the universe.

In the case of our own moon, as we have only two terms, Earth's semi-diameter and Moon's orbital major-axis, the harmonic equation is indeterminate; its direct solution is, therefore, impossible. I have elsewhere, however, called attention to the fact that Earth is central, in the belt which is bounded by the secular perihelion of Mercury and the secular aphelion of Mars, and this fact, together with the nearly synchronous rotation of all the planets in the belt, may be regarded as indications of common forces, such as would be likely to lead to common harmonies. The sixth and seventh divisors of the Mars series represent, respectively, the ratio of Earth's semi-diameter to Moon's major-axis, and the ratio of Earth's axial rotation to its orbital revolution, viz.:

$d_6 = 3\ d_5 - d_1 = 122.$ $\quad 120{\cdot}5331 =$ Moon's major-axis.
$d_7 = 3\ d_6 - d_1 = 365.$ $\quad 365{\cdot}2564 =$ Earth's year.

The satellite-systems of Jupiter, Saturn, and Uranus, all present unmistakable evidences of harmonic influences, some of which I propose to embody in a future article. Meanwhile, some of the readers of the JOURNAL may, perhaps, like the entertainment of trying to study them out by themselves.

HAVERFORD COLLEGE, *Oct.* 17*th*, 1877.

Jablochkoff Light.—In the second trial at the West India docks in London, a very large court was first lighted by four electric candles, softened by ground glass, so that the eye could read small characters at a great distance, without being dazzled or fatigued. The exterior and interior of many buildings on the wharves were then successfully illuminated. The light of each candle was equivalent to 100 gas-burners. The carbons which were enclosed between the porcelain plates worked easily, and the light was not of a very long duration.—*Les Mondes.* C.

New Vulcanizing Method.—MM. Turpin Frères have received a platinum medal from the Société d'Encouragement, for new applications of caoutchouc and gutta-percha, the hardening being effected by magnesia.—*Les Mondes.* C.

MEASUREMENT OF WATER MECHANICALLY SUSPENDED IN STEAM.

By Palamede Guzzi, C. E.[1]

The greatest difficulty which is encountered in determining the coefficient of evaporation of a steam generator, or the weight of vapor produced in a given time, is in measuring the water which it carries over from the boiler by mechanical action.

This problem, which has acquired a greater importance since Hirn, Leloutre, and Hallauer, by their overthrow of the old theories of the steam engine, have opened the way to the true theory, is not yet completely solved.

The only solution of real importance, among the many which have been hitherto attempted, is the one suggested by Hirn, and followed by the distinguished experimenters of the Industrial Society of Mulhouse, and others. Even this leaves some uncertainty, so that the Mechanical Committee of that society has recently renewed its offer of a reward for a better method.

Hirn's plan consists in measuring the total heat of a given weight of steam, and comparing it with that which would be found in dry, saturated steam, as given by Regnault's formula. His apparatus consists simply of a coiled tube, surrounded by water.

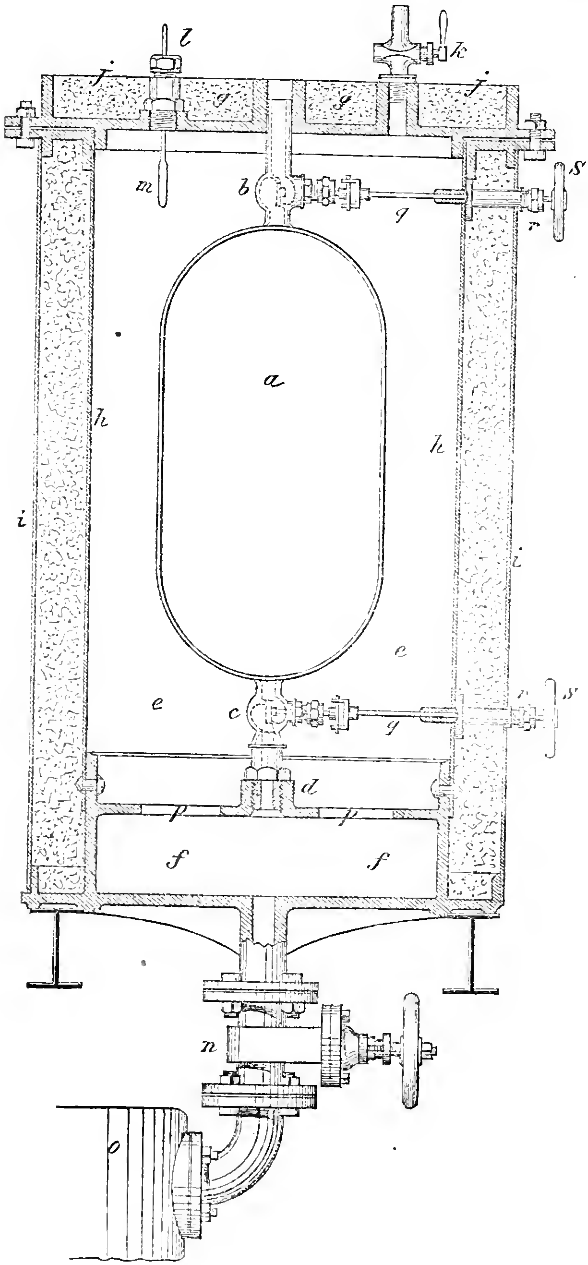
But there is some indeterminate portion of the energy of the steam, which is so transformed as to be incapable of measurement. The vibrations generated by the flow of steam, in the coil, and in the surrounding water and air, as well as in the boiler itself, represent a transformation of heat into mechanical energy. A part is manifested in the form of sound, and is lost; only a small fraction of the remaining portion can reappear in a greater elevation of the temperature of the water. Moreover, during the flow of steam and its condensation in the coil, recent experiments have shown that there is a conversion of thermal into electric energy.

It is true that Regnault's experiments were made under similar conditions; but for that very reason there is a greater need of other means of experimenting for purposes of comparison or confirmation.

I have devised an apparatus, consisting mainly of a vessel which is filled with the steam of which it is desired to measure the humidity,

[1] Abridged from a communication to the Milan College of Engineers and Architects, January 21st, 1877.

and which is protected, as much as possible, against radiation and consequent internal condensation. Its capacity, and the weight of the vapor contained in it, being known, it is easy to ascertain the amount of dissolved or suspended water.



This recipient, marked *a* in the accompanying diagram, is made of copper, in the form of a cylinder with hemispherical ends. It has an upper valve *b*, and a lower valve *c*, which is fastened by the screw *d*, to the bottom of the chamber *e*. This chamber, which serves as the envelope of the recipient *a*, is formed of the double bottom *f*, and the cov-

er g, which are both of cast iron, and the cylindrical sheet-iron wall h. The sides and top are protected by non-conducting materials, enclosed in the external envelopes i, j, which are made of polished brass. The covering receives pipe leading to the valve b, and contains the stop-cock k, as well as the stuffing-box l, through which passes the stem of the thermometer m.

The double bottom f is put in communication, by means of the receiving valve n, with the steam-dome o; by means of the openings p, with the chamber e; and, when desired, with the interior of the recipient a. The valves b and c are worked by means of the hand-wheels s, and the spindles q, which traverse the stuffing-boxes r. In order to diminish, as much as possible, the transmission of heat from b and c to s, the spindles are made hollow, and pierced with holes, so as to increase the surface of contact with the steam of the envelope e, while the heat conducting sections are diminished.

In experimenting, the air is driven from e by opening k and m; k is then closed, and after some time b and c are opened. After the air is driven from a, b is closed. After some seconds, when the equilibrium of pressure is established, c and n are closed; the cover g is lifted, and the spindles q being withdrawn, the recipient a is removed to be weighed. The total weight, less the weight of the receptacle, gives the weight of the mixture of water and steam; deducting the weight of an equal volume of dry saturated steam at the same temperature, we obtain the quantity of water dissolved in the steam.

Care is needed in determining the tare of the vessel a. To take account of the vapor which is condensed upon the inner walls of the vessel and adheres to them, it will be well to experiment with a generator from which no other vapor has been withdrawn, and which has not been heated for some time. Subtracting from the weight of a, thus filled with vapor, that of an equal volume of dry saturated vapor at the same temperature, we get the weight of the empty vessel, but internally bathed; this is the tare.

The apparatus could also be applied to the determination of the density of dry saturated vapors, under high pressures, for comparison with the results of Fairbairn and Tait,[1] and to find the values of r, in the formula of Clausius,

$$A\,P\,u = \frac{r\,P}{T\dfrac{d\,P}{d\,T}}$$

for comparison with those obtained by Regnault.

[1] *P. Mag.* [4], lxii, 230.

MEASUREMENT OF WATER MECHANICALLY SUSPENDED IN STEAM.

By J. B. Knight.

Having for a long time felt the want of a more satisfactory method of determining the amount of water carried out of the boiler by the mechanical action of the steam, when determining the evaporative efficiency of steam boilers, I conceived a device, about January 1st, 1874, which, so far as depending upon the weight of a measured quantity of entrapped steam, was identical with that of Palamede Guzzi, an account of which is given on page 355.

Preferring to submit my design to the test of experiment before publishing it, and being prevented from doing so up to this time, Mr. Guzzi is, of course, entitled to the claim of priority.

It now becomes desirable, however, that I should give my plan, as it covers some points not embodied in his, and which seem essential to the accuracy of the result.

The advantages claimed for my plan are: entrapping the steam to be tested, in exactly the condition in which it passes from the boiler in the normal condition of working; and depending entirely upon the weight of the steam entrapped, thus avoiding errors arising from losses of heat during the experiment.

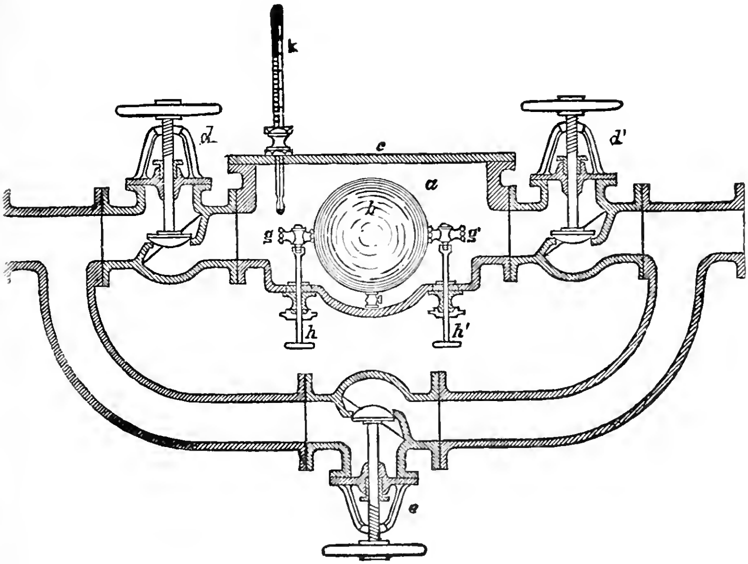
All the methods heretofore proposed, including that of Mr. Guzzi, fail entirely in one or the other of these particulars.

The article referred to gives the plan of Prof. G. A. Hirn as the best yet suggested, and which consists in measuring the total *heat* of a given weight of the steam under examination, and comparing it with that of dry saturated steam at the same pressure and temperature. The apparatus there described consists of a simple condensing coil.

Another form of apparatus for this method is that used in the boiler tests at the Centennial Exhibition, and described in detail on p. 111, current vol., and is considered the best in use in this country.

By this method, whatever the apparatus used, corrections have to be made for losses by radiation from the conducting pipe and condensing vessel, and for absorption by the vessel, if of wood, and the specific heat of the vessel, and of the stirring apparatus, none of which can be more than approximately ascertained.

In the apparatus of Mr. Guzzi, the copper vessel in which the steam is to be weighed, is enclosed in, and filled from, an outside chamber with non-conducting sides, connected by a pipe to the steam dome of the boiler. With this arrangement, the steam, not being taken from the principal outlet of the boiler, is not of the normal quality, and is subject to some loss of heat by radiation from the chamber and connections. Moreover, after entering the weighing vessel, the steam is allowed to stand in a quiet state, and all the water held in suspension will be precipitated.



The apparatus proposed by myself is shown in the figure, as intended to be inserted in the steam-pipe leading to the engine. A chamber *a*, formed by an enlargement of the pipe, has an opening at the top, large enough to admit the vessel *b*; the opening to be covered by means of the lid *c*. At each end of the chamber are the stop-valves *d d'*, and just beyond these is a by-pass, having in it the valve *e*. It is obvious that when the valves *d d'* are open and *e* closed, all the steam, on its way to the engine, must pass through the chamber *a*; or if it be desired to open the chamber, the valves being reversed, the steam will pass around the chamber through the by-pass.

The copper vessel *b* (made spherical in form for the purpose of enclosing a given space with the least weight of metal), has outlets on each side through the cocks *g g′*, operated by the handles on the spindles *h h′* passing through the bottom of chamber *e*. At the bottom of the vessel *b*, and operated from the outside in the same manner as the cocks *g g′*, is a small cock *i*, by means of which any water resulting from heating it up to the temperature of the steam can be drawn off.

In the lid or cover of the chamber is a stuffing-box, through which is inserted the thermometer *k*, for the purpose of ascertaining the temperature of the steam; the pressure being taken from a gauge attached to the boiler.

The mode of operating is as follows: Place the copper vessel *b* in position, with its outlets open and in line with those of the chamber *a*, the drain cock *i* also being open, and when the boiler is in full action open the valves *d d′*, and close *e*. All the steam thus being caused to pass through the chamber *a*, through and around the copper vessel *b*, the steam in the latter must be, in every particular of temperature, pressure and saturation, in exactly the same condition as all that leaves the boiler.

When this has continued for a sufficient length of time to insure the proper heating of the chamber and its contents, close the cocks *g g′* and *i* simultaneously, and we have entrapped in the vessel *b* a quantity of steam of the quality due to the normal working of the boiler.

Now open the valve *e* and close *d d′*; remove the lid *c*, when the vessel *b* may be taken out and weighed. From this weight deduct that of the empty vessel, and the remainder will be the weight of the mixture of steam and water contained in it. A comparison between this and the weight of the same volume of dry saturated steam at the same temperature, will give the percentage of water carried out of the boiler by the mechanical action of the steam.

It is evident that no allowances have to be made for radiation, or for the specific heat of the materials used, as we simply weigh the supersaturated steam carried from the boiler in actual service, and compare it with dry saturated steam.

New Motor.—Ferdinando Tommasi has recently constructed a "thermo-dynamic motor," in which work is done by the mere dilatation of oil, without change of state.—*Nature*. C.

JOURNAL

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OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CIV. DECEMBER, 1877. No. 6.

Franklin Institute.

HALL OF THE INSTITUTE, Nov. 21st, 1877.

The stated meeting was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present 111 members and 25 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting the following donations were made to the Library:

Kanton Bern. Statistik eines Theiles der kantonalen Bauverwaltung, 1875. From S. L. Smedley.

Tables and Formulæ useful in surveying, geodesy and practical astronomy. Washington, 1873.

Report on the Defences of Washington to the Chief of Engineers, U. S. A. By J. G. Barnard. Washington, 1871.

Report on the fabrication of iron for defensive purposes. Washington, 1871. With Supplement. Washington, 1872.

Report upon the physics and hydraulics of the Mississippi River. By Humphrey & Abbot. Washington, 1876.

Practical tables in meteorology and hypsometry. By R. S. Williamson. New York, 1868.

On the use of the barometer on surveys and reconnoissances. By R. S. Williamson. New York, 1868.

Report on the effects of firing with heavy ordnance from casemate embrasures. By J. G. Totten. Washington, 1857.

Treatise on the various elements of stability in the well proportioned arch. By D. P. Woodbury. New York, 1858.

Official report to the U. S. Eng. Dep't of the siege and reduction of Fort Pulaski, Georgia. By Q. A. Gillmore. New York, 1862.

Sustaining Walls. By D. P. Woodbury. Washington, 1854.

From the Chief of Engineers, U. S. A.

Report on the meteorological, magnetic and other observatories of the Dominion of Canada, for 1876. Ottawa, 1877. From the Meteorological Office.

Pottery and porcelain. Hand book for the use of visitors in the Museum of Art. New York, 1875. From E. Hiltebrand.

Journal of the Royal Geographical Society, Vol. 46, 1876. From the Society.

Tables for determination of Minerals. By Persifor Frazer, Jr. From J. B. Lippincott & Co., Publishers.

Annual report of the Secretary of the Navy, for 1876. Washington, 1876. From the Secretary.

English Patent Specifications and Drawings for 1876 (No. 1, Jan. 1, to No. 4800, Dec. 12). From the British Patent Office.

Bulletins of the United States National Museum. No. 7. Contributions to the natural history of Hawaiian and Fanning Islands and Lower California. By Thos. H. Streets. Washington, 1877.

No. 8. Index to the names which have been applied to the subdivisions of the class Brachiopoda. By W. H. Dall. Washington, 1877.

No. 9. Contributions to North American Ichthyology. No. 1, by D. S. Jordan. Washington, 1877.

Bulletin of the United States Geological and Geographical Survey of Territories, Vol. 3, No. 4. Washington, Aug., 15, 1877.

Synopsis of the Flora of Colorado. By Thos. C. Porter and J. M. Coulter. Washington, Mar. 28, 1874.

Rules and list of Members of the Royal Society of New South Wales, 1877.

Birds of the Northwest. By E. Coues. Washington, 1874.

Ninth report of the U. S. Geological and Geographical Survey of the Territories, 1875. By F. V. Hayden. Washington, 1877.

Fur Bearing Animals. By E. Coues. Washington, 1877.

Ethnography and Philology of the Hidatsa Indians. By Wash. Mathews. Washington, 1877.

Contributions to North American Ethnology, Vol. 1. Washington, 1877.

Monographs of North American Rodentia. By Coues and Allen. Washington, 1877.

The Vertebrate of the cretaceous formations of the West. By E. D. Cope. Washington, 1877.

From the Hon. Secretary of the Interior, Washington.

Report of the Commissioner of Agriculture, for 1876. From the Commissioner.

Specifications and Drawings of Patents, for May and June, 1877. From the U. S. Patent Office.

Statistics of Mines and Mining in the States and Territories west of the Rocky Mountains, being the eighth annual report of R. W. Raymond. Washington, 1877. From the Author.

Practical treatise on Water Supply Engineering. By J. T. Fanning. New York, 1877. From D. Van Nostrand, N. Y.

Annual report of the Chief Engineer of the Water Department of Philadelphia, for 1876. From W. H. M'Fadden, Chief Engineer.

Small's Legislative Handbook. Harrisburg, 1877. From H. O'Neill.

Methods, discussions and results, meteorological researches for the use of the Coast Pilot. Part 1. Washington, 1877. From the Sup't U. S. Coast Survey.

Brief treatise on U. S. Patents, for inventors and patentees. By H. & C. Howson. Philadelphia, 1877. From the Authors.

Mr. William Welsh, chairman of the Committee on Primary Industrial Education, made a verbal report of progress, and presented the following resolutions :

1. "*Resolved*, That the Franklin Institute respectfully urges the Board of Education, and the Select and Common Councils of this city, to provide a thoroughly competent Superintendent of Drawing, who will not only instruct teachers in that practically important department, but will also assist in its introduction into all the Public Schools of this great manufacturing city."

2. "*Resolved*, That the Committee on Primary Industrial Education be authorized to add to its number from members of the Institute."

3. "*Resolved*, That Mr. John D. Runkle, President of the Massachusetts School of Technology, be invited to address the members of this Institute, on Primary Industrial Education, at such time as will suit his convenience; and that an invitation to attend the lecture be extended to the Board of Education, and the Directors and Officers of Girard College and the Pennsylvania Institution for the Deaf and Dumb, and the Directors of the Pennsylvania Museum of Industrial Art."

4. "*Resolved*, That the Franklin Institute, without committing itself to the details of the plan submitted by Prof. Ennis, gives its cordial approval of increased instruction in Natural Philosophy in our public schools, as a proper basis for industrial education."

On motion, the first and second resolutions were adopted; the third was referred to the Standing Committee on Instruction; and the fourth was recommitted to the Committee.

Mr. Hector Orr read the paper announced for the evening, on the Culture and Manufacture of Flax, Hemp, Jute and Ramé.

Mr. Samuel James gave an illustrated description of Seyss's Automatic Weighing and Sorting Machine for coins, now in use at the Philadelphia Mint.

The Secretary exhibited the apparatus, and described the methods employed to measure the power and light, and Prof. E. J. Houston, that for the electrical measurement, in the tests of dynamo-electric machines now being made by the Institute.

A letter was read, from Frederick Ransome, Esq., London, Eng., acknowledging receipt of notice of election as an honorary member of the Institute.

Mr. J. E. Mitchell offered the following, to be acted on at the next meeting of the Institute:

"*Resolved*, That the By-Laws of the Institute be amended by striking out all of Sections 5 and 7 of Article II."

On motion, the meeting adjourned.

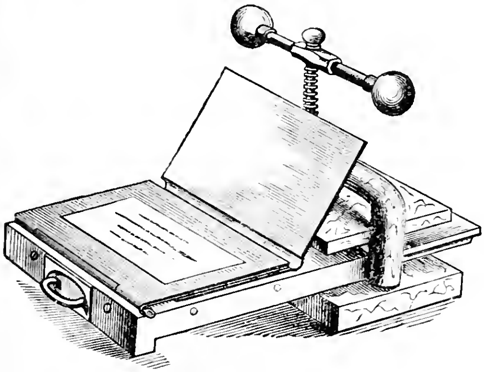
J. B. Knight, *Secretary.*

ZUCCATO'S PAPYROGRAPH.

Report of the Committee on Science and the Arts of the Franklin Institute. Adopted August 1st, 1877.

The Papyrograph is a new process for the rapid production of facsimile copies of manuscripts, pen drawings, &c. It was invented by Eugenio De Zuccato, of Padua, Italy, and patented in the United States November 24th, 1874, and January 4th, 1876. * * * * The process is very simple, and may be briefly described as follows:

The Company holding the patent, supply, to their licensees, sheets of paper that have been made waterproof by a resinous, flexible varnish, applied on one side of the paper; on the opposite side, the manuscript or drawing is to be executed with a steel pen, using a special ink composed of a concentrated alkaline solution with suitable coloring matter added to it. The effect of this ink wherever it touches the paper is to destroy its waterproof quality by attacking the varnish. The sheet is then floated on the surface of water, the written side uppermost, and in a few minutes the water makes its way up through the paper to the alkaline ink, and completes the solution of the varnish at those points. It is then brushed with a camel's hair brush and plenty of water, and all the dissolved varnish washed out of the pores of the paper, thus producing a porous stencil of the manuscript. A special printing ink or "color" is furnished, composed of glycerine and aniline violet; a small quantity of this color is brushed over the written side of the stencil sheet and it is then placed face downwards on a printing pad of velvet, which has been previously saturated with the same "printing color."



A waterproof folio is furnished, having a central leaf made of heavy sheet zinc, with an aperture slightly larger than the printing pad; the pad with the porous stencil being properly placed in the

folio, the zinc is turned down so that the marginal frame holds the stencil sheet in place on the pad, and then all is ready for printing. All that is now necessary is to place a sheet of ordinary paper on the stencil, close the folio on it, slide the whole into an ordinary copying press and apply a slight pressure for a moment; a portion of the color is forced through the stencil to the clean sheet in contact with it, and the copy is complete.

Several hundred copies may be printed from the one stencil, and without replenishing the printing color in the pad beneath it.

It will be seen by the foregoing description, that all the manipulations are simple and easily acquired, the materials and apparatus always ready and in order for immediate use. In the opinion of this committee, these are great advantages over any other method which they know of for duplicating manuscripts.

The copies are fac-similes of the originals, with all the characteristic light and heavy touches of the pen, and music can therefore be well duplicated.

We suppose it is possible for the manufacturers to make other colored inks besides the violet one now furnished, and if so, we think that a more permanent ink is desirable than one made of aniline.

In conclusion, the committee commend the invention for its ingenuity, simplicity, and its easy application to the many practical uses for which it is adopted.

(Signed), SAMUEL SARTAIN,
OTTO SUTHY,
HENRY R. HEYL,
Sub-Committee.

Lontin Magneto-Electric Machines.—Among the many candidates for favor in electric lighting, plating, etc., are the dynamo-electric and magneto-electric machines of Lontin & Co., 24 Rue Cassette, Paris. They are made both for continuous and for reciprocating currents, and the same machine may be used either as a motor or for lighting, or simultaneously for both objects. The regulation of the light is said to be so perfect, that it is specially adapted for naval service; pitching, rolling, wind, and the other inconveniences of navigation, have no influence on the steadiness of the light.—*Les Mondes.* C.

Writing Machine for the Blind.—M. Recordon, of Geneva, has invented a machine which enables the blind to write, both in characters which can be read by their blind companions, and in ordinary letters. He proposes to publish a journal for the blind, of which the first number will be issued at Geneva, Jan. 1, 1878.—*Les Mondes.* C.

Electric Conductivity of Trees.—Th. du Moncel reports a series of careful experiments upon the conductibility of trees. He finds a resistance, when the leaves are the points of contact, equivalent to from 200,000 to 400,000 kilometres of telegraph wire. In moderately large trees, at a height of 7 or 8 metres on the trunk, it is about 3000 kilometres.—*Comptes Rendus.* C.

Electrical Relations of Capillary Constants.—M. Lippmann reports experiments, conducted in the laboratory of Jamin, which show that for every value of electro-motive force, the capillary constant (or superficial tension) has only one value, whatever may be the chemical composition of the liquid. In other words, if the electro-motive force of two different combinations is the same, the capillary constant is also the same.—*Comptes Rendus.* C.

Vapor Density and Elasticity.—Alexander Morton publishes some ingenious and interesting experiments on the maximum elasticity and density of vapors. He finds that absolute alcohol and chloroform vapors have equal elasticity at a temperature a little above that of melted lead; that there is a temperature at which steam and bisulphide of carbon have equal elasticities; that cloroform may be vaporized and re-liquefied at a still higher temperature.—*Proc. Phil. Soc., Glasgow*, v. x. C.

Meteoric Rupture.—Showers of meteoric stones have been attributed, by Haidinger and others, to the joint attraction of separate bodies, forming a cluster which enters the atmosphere as a single mass. Maskelyne supposed that the detonations in the upper air, were due to the expansion of the outer portions, while the interior retained the extreme cold of the celestial spaces. Benzenberg sought an explanation in electric discharges, produced by violent friction. Daubrée has experimented with dynamite and steel, to show that "the fragmentary form of meteoric irons may be attributed to a rupture under the action of strongly compressed gases."—*Comptes Rendus.* C.

Diamagnetism of Hydrogen.—R. Blondlot finds that condensed hydrogen has diamagnetic properties of considerable energy, and that the diamagnetism increases in a greater ratio than the condensation. His experiments confirm some of the conclusions which Tyndall published in his researches upon crystalline bodies.—*Comptes Rendus.* C.

Nitrogen of Plants.—Berthelot has experimented upon the absorption of nitrogen by organic compounds, under the action of feeble electric currents, analogous to those which pervade the soil. He finds that he can thus account for the "unknown source" of vegetable nitrogen, which Lawes and Gilbert observed in their agricultural experiments at Rothamsted.—*Comptes Rendus.* C.

Forms of Molecules.—Prof. J. Clerk Maxwell, reasoning from the conclusions of Boltzmann's paper "on the nature of gas-molecules," concludes that the molecules of chlorine, ammonia and sulphureted hydrogen, are rigid elastic bodies; those of hydrogen, oxygen, nitrogen, air, carbonic oxide, nitrous oxide and hydrochloric acid, are smooth figures of revolution; and those of mercury-gas are smooth spheres.—*Nature.* C.

Venetian Sewerage.—The square of St. Mark, in Venice, is often flooded by the spring tides. Engineer Domenico Asti proposes to remove the inconvenience by conduits which will hold the greatest quantity of rain that ever falls in six hours, with self-acting gates, which open at low tide and exclude the waters of the lagoon at high tides. By an expenditure of $20,000, he thinks that all inundations could be prevented, except in the few very exceptional cases which occur only at intervals of many years. His paper is accompanied by drawings and detailed calculations.—*Il Politecnico.* C.

Electric Lighting.—The experiments with the Gramme machines are now daily repeated at the Palais de l'Industrie, in Paris. An area of 12,000 square metres is lighted by two electric lustres, of six lamps each, suspended at 27 metres from the ground. The power is supplied by two steam engines of 25 horse-power each. It would take 10,000 candles to yield an equivalent light on the floor, or 300,000 to illuminate the whole space as thoroughly. The subdivision of the light has been very successful. At first there was but a single lustre, then there were two, and it is proposed soon to introduce three.—*Les Mondes.* C.

Rail-Profiles.—Moritz Pollitzer, chief engineer of the Austrian "Staats Eisenbahn-Gesellshaft," has investigated the sections of steel rails, with a view to determine the profile which will give the greatest wear at the least cost.—*Zeit. des Oester. Ing.- und Arch.-Verein.* C.

Manganese Bronze.—According to Gintl, a tough, malleable bronze, of nearly the color of brass, contained 76·710 parts copper; 16·147 manganese; 5·490 zinc; ·320 iron; ·762 tin and silicon. This represents an alloy of 15 parts copper, 4 parts manganese, and 1 part zinc.—*Techn. Blätter; Dingler's P. Jour.* C.

Spectrum-Projection.—By means of a Leyden jar and induction coil, and three Bunsen cells of 2 gallons, clear and continuous spectra can be projected on the screen, without a calcium light. The spectral lines are zigzag, like the sparks from the coil. Soda, copper, zinc, calcium, and brass, may be satisfactorily employed.—*Les Mondes.* C.

Sketching-Paper.—MM. Carl Schleicher and Schüll, of Düren, Germany, prepare rolls of sketching-paper of excellent quality, and uniformly ruled in squares of 1 centimetre, ½ centimetre, and 1 millimetre on the side. The difference in the breadth of the rulings is so plainly marked that any projections can be readily made, without instrumental measurements.—*Pap.-Zeitung.* C.

Microscopic Organisms.—In two important papers, presented to the French Academy on April 30 and July 16, MM. Pasteur and Joubert show that the terrible animal disease which is known as *charbon* or *sang de rate* (carbuncular gangrene), is caused by microscopic bacteridia, which were first observed by Dr. Davaine, in 1850. It may, therefore, be classed with trichinosis and the itch, as a parasitic disorder. Vibrios, bacteria and bacteridia, are all found under two essentially distinct forms; either in translucent threads of variable length, multiplying rapidly by division, or in groups of little brilliant corpuscles formed in the interior of the threads, which separate from the parent, and constitute an apparently inert mass of points, from which countless legions of filiform individuals may come, having the same two-fold methods of reproduction. The threads may be killed by drying, or by a heat much below that of boiling water. The germs, when dry, withstand temperatures from 120° to 130° C., or 248° to 266° F.—*Comptes Rendus.* C.

African Scientific and Hospital Station.—The International African Association has established a depot at Zanzibar, and an agency in the Uniamwesi, which will enable it to place its first scientific and hospital station on the borders of Lake Tanganyika, or still farther in the interior.—*Comptes Rendus.* C.

Detection of Butter-Adulteration.—To determine whether butter has been mixed with inorganic or animal fats, P. Jaillard places a thin film between two strips of glass and examines it microscopically. If the butter is pure, only fatty globules can be seen; if it is adulterated, there will also be crystalline ramifications in greater or less quantity.—*Les Mondes.* C.

Confirmation of Franklin's Electrical Theory.—Edlaud has investigated the electrical currents produced by the flow of liquids in tubes. He finds that the existence of the currents cannot be explained satisfactorily by Du Fay's hypothesis, but that it can easily be accounted for by the theory of excess or deficiency in a single fluid.—*Pogg. Ann.*, clvi. C.

Domestic Use of Aluminum.—Recent experiments show that pure aluminum could be employed much more extensively than has generally been supposed, provided a cheap method was devised for procuring it. Spoons made from aluminum, from German silver, and from silver, were subjected for a year to constant use, under similar conditions. The resulting wear was 0·630 per cent. for aluminum; 1·006 per cent. for German silver; 0·403 per cent. for silver.—*Berg- u. Huetten-Zeit.* C.

Mousseron Brazier.—Abbé Moigno gives a detailed and interesting description of a brazier, invented by M. Mousseron (20, Boulevard des Filles-du-Calvaire, Paris), which may be used in close apartments without vitiating the air. Through the centre of the fire box, passes a tube pierced with holes, which admits a copious supply of air to the fuel, producing a vivid combustion, so that there is no production of carbonic oxide. The carbonic acid is absorbed by the vapor of water from a vessel near the top of the brazier, and escapes into the room in a harmless form. Numerous extracts are given from a report of M. Triboulet to the *Societé Nationale des Architectes de France*, and the invention is pronounced "the easiest, the most universally applicable, the most economical and the most agreeable of all the known methods of warming."—*Les Mondes.* C.

Indicator for Hot Journals.—M. Coret has contrived a simple apparatus for giving an alarm, when boxes are not sufficiently greased. It embraces a certain number of metallic tubes with elastic bottoms, filled with an expansible liquid, the whole enclosed in a small metallic cylinder. The instrument can be attached to a turning arbor, and if the arbor heats, the liquid dilates, forming an electric contact, which sounds an alarm.—*Soc. d'Encour. pour l'Ind. Nat.* C.

Abridged Labor.—In a paper on the division of the circumference into equal parts, Ed. Lucas introduces a process for accomplishing a calculation in thirty hours, which would have required three thousand years of constant labor under the old methods. It would take more than two hundred million centuries, at the rate of ten figures per second, to simply write out the numerical value of a quantity for which the expression can be written, in his formula, in less than half a second.—*Comptes Rendus.* C.

Wages-Insurance.—The Industrial Society of Reims recommends an addition to policies of insurance against fire, of a clause, providing for the payment of wages to the workmen, during the time that they are thrown out of employment by the necessary repairs. The proposal receives a qualified approval from a committee of the Industrial Society of Mulhouse, with a recommendation that the Alsatian custom, of reserving a fund in each establishment for such contingencies, should be more generally adopted.—*Bull. de la Soc. Ind. de M.* C.

Uses of Injectors.—The *Journal des Fabricants de Sucre* describes various economical applications of the Körting injector, in the removal of gases, liquids and solids. In chimneys that are sufficient for a given number of boilers, the addition of another boiler often weakens the draft, which may be restored by an injector. In one instance, two boilers were required, using in 230 hours, 78,120 kilogrammes of coal; after adding a Körting injector, only 36,375 kilogrammes were consumed in the same time for the same work, and only one boiler was required. The same injector has also been used as a smoke consumer; as a blower for stoves; as an extractor of carbonic acid gas; as a pump for well water, for thick and muddy liquids, for beet-juice, for milk of lime, for acids, for lyes and for locomotives at watering stations; as an elevator for animal-black, for grain and for granular solids; and as a sugar clarifier. C.

Anemometer Vane.—H. Wild has improved the anemometers of Pickering and others, so as to secure greater simplicity of construction, together with a more accurate measurement of the wind-force. Under deviations of 30° C. in the thermometer, and 80 millimetres in the barometer, the error of registered velocity would not exceed 5 per cent.—*Les Mondes.* C.

Self-Winding Clock.—F. Helling describes an automatic clock, in which the winding machinery is operated by the alternate expansion and contraction of glycerin, or other suitable liquid. A piston, on the surface of the glycerin, is so connected with ratchet wheels and toothed racks, that motion in either direction will wind up the weight. The inventor thinks that the contrivance will be especially valuable for self-registering meteorological instruments.—*Zeit. des Ver. Deutsch. Ing.* C.

Hydraulic Cement.—An excellent cement for foot-walks, and for all uses which require exposure to the weather or to dampness, is described in *Der Practische Maschinen-Constructeur.* It is made by thoroughly stirring Portland cement, or good hydraulic lime, into a warm solution of glue, so as to make a thick paste, and applying it immediately. In three days it acquires extraordinary hardness and tenacity. It is an excellent cement for joining the porcelain heads to the metal spikes which are used as ornamental nails. C.

Cosmical Meteorology.—At the meeting of the French Academy, on July 30th, M. Faye called attention to the supposed importance of looking for cosmical influences, wherever any cyclical meteorological disturbance is discovered. If the Greek astronomers had known of the daily tides, he thinks they would have known the earth's true place in the system, and discovered the law of gravitation. But he claims that the alleged cosmic influences are mysterious; that they have never taught us anything about the nature of the phenomena, and that we have reason to doubt whether the cosmic action is real. He proposes, as a criterion, that a simple resemblance of period is not enough, unless there is an *a priori* reason for conceiving the possibility of some bond between the phenomena. Applying this criterion, he disparages the labors of Wolf, Schwabe, Carrington, Lamont, Broun and others, who have sought to trace connections among sun-spots, magnetic variations, storms, and planetary influences. C.

Fire-Damp Explosions.—The *Annales des Mines* (T. xi, liv. 2) gives three papers on the relations of atmospheric pressure and coal dust, to explosions of fire-damp, and on the best means of preventing them. The French Academy has appointed MM. Daubrée, P. Thenard, and Berthelot, a committee to act with a committee of engineers, in studying remedial measures. C.

Crystallized Glass.—M. Videau, director of the Blanzy glass works, has obtained some fine specimens of crystallized glass, from a crucible that had been running for eight months and a half, in a Siemens furnace. He hopes to obtain still better crystals, together with the "mother-waters," from a furnace that seems likely to act for nine or ten months.—*Comptes Rendus.* C.

Discovery of Springs.—M. Baour states that in many cases, permanent supplies of subterranean water may be found by observing the quivering of the air on a clear summer day, when the sun is near the horizon and the air is still. By the aid of an assistant with two beacons, the outlines of the quivering area may be marked out, and wells dug at convenient points. The success of "divining-rod" wielders may, perhaps, have often arisen from a knowledge of this method.—*Les Mondes.* C.

Meteors.—In his closing communications to the French Academy, M. Daubrée gives an interesting summary of the various meteoric phenomena and markings which have been satisfactorily explained by his experiments with dynamite. Popular theories had previously assumed that there should be some such explanation, but positive evidence was wanting. In like manner, Abbé Nollet had pointed out resemblances between lightning and electricity, but the identity was not demonstrated until Franklin drew the lightning from the skies in 1752. C.

Influence of Trees on Moisture.—M. Fautrat has made observations in French forests, to determine the influence of trees on the distribution of rain and moisture. He finds that forests receive more rain than open plains, and pines more than leafy trees. Pines retain more than half of the water that is precipitated upon them, while leafy trees allow 58 per cent. to reach the ground. Pines, therefore, furnish the best shield against sudden inundations, and the best means for giving freshness and humidity to a climate like that of Algiers.—*Comptes Rendus.* C.

Improvement in Agricultural Analysis.—M. Ad. Cornot gives a new method of determining the proportion of potash in soils or mixtures. The analysis can be made in a few hours, the determination being as exact as if a much longer time had been employed. —*Comptes Rendus.* C.

Slipping of Locomotive Wheels.—M. Rubeuf finds that the slipping of locomotive wheels, on down grades, varies between 13 and 25 per cent. There is, consequently, a great loss of fuel, and a great wear of tires and rails, from this cause alone, which is deserving of special study.—*Comptes Rendus.* C.

Pasteur's Triumphs.—Bastian has withdrawn from the proposed test of his views by the French Academy, on account of dissatisfaction with the constitution of the committee. P. Bert has given his full adhesion to the interpretation which MM. Pasteur and Joubert gave to their experiments upon carbuncular gangrene. In a communication presented to the Academy on July 30th, he states that he has successfully repeated the experiments, which show that the virus is due to living bacteridians. C.

Orbit of a Bolide.—M. Grucy, by combining observations at Bordeaux, Augouleme and Clermont, has calculated the orbit of a bolide, which he found to be within 23° of its perihelion. Its velocity, relative to the earth, was 68 kilometres, or about 45 miles, per second. Its orbit, like some of those calculated by MM. Galle, Tissot and Heiss, was very hyperbolic; it must, therefore, have come into our system from the stellar spaces.—*Les Mondes.* C.

The Plethysmograph.—M. Mosso, of Turin, has invented an instrument for observing the variations in the circulation of blood in the arms, under the influence of natural or artificial causes. The entrance of a person into the room, causes a diminution of the forearm, which may vary between 4 and 15 cubic centimetres, the blood quitting the arm and mounting to the head. Thought and cerebral activity seem to be in proportion to the contraction of the vessels of the forearm. During sleep, dreams cause a depression in the circulation of the arm. Just before waking, there is a like depression. The experiments confirm the theory of Durham, Hammond and Ehrmann, that the brain receives less blood during sleep, than when awake.—*Les Mondes.* C.

Book Notices.

THE ELEMENTS OF DESCRIPTIVE GEOMETRY, SHADOWS AND PERSPECTIVE.—With a brief treatment of Trihedrals, Transversals and Spherical, Axonometric and Oblique Projections. By D. Edward Warren, C. E. 8vo, pp. 282, with detached plates. Jno. Wiley & Sons. New York, 1877.

Having carefully examined the above work, especially with reference to discovering its advantages over other similar works, we find that the ordinary classification of lines, surfaces and volumes is retained, but the order of demonstrations is somewhat modified by treating each class of objects under the four divisions: A, Projections; B, Tangencies; C, Intersections; D, Developments. The objects treated of in Orthographic Projections are divided into the two grand divisions of Surfaces of Revolution and Transposition. The latter class is defined to be that including all surfaces generated by a "line moving in any other way than by revolution about a fixed axis." As many surfaces, such as planes, single curved and some warped, may be formed by both methods, they are classed and treated under both divisions, leading to a separation of principles and problems otherwise closely related, as well as to a redundancy which strains the attention.

In the analysis of the individual problem, the author states first the theorem, then the description of the positions and motions *in space*, and lastly *in projection*. We do not think the discussion of the positions *in space*, gives so clear an idea nor does it develop so well the conceptions of methods, as a brief analysis stating concisely the principles to be employed. Neither have we found any new matter nor methods. The use of the word *trace* to designate the point in which a line pierces the planes of projection, introduces an ambiguity, as the same word also denotes the intersection of those planes by any third plane, thus confusing the student. The drawings in oblique projection, showing at once the objects in space as well as their projecting lines and projections, may be of service to the beginner, but these features may be much better illustrated by card-board models or a hinged blackboard with a perforated glass triangle for an oblique plane, and glass or wooden rods for lines. In short, we cannot see that the work is any improvement upon those of the same nature now in use, some of which cover almost the same ground in about one-half the number of pages.

H.

INDUSTRIAL DRAWING.—By Daniel F. Thompson. 8vo, pp. 209. New York, 1877. John Wiley & Sons. Price, $3.50.

This is a revised edition of a work by the late Prof. Mahan, which has been enlarged by the addition of chapters on Tinting, Shading, Shadows, Isometric and Oblique Projections, and Perspective. The classification is good and the language plain, but we are unable to find much new matter in the work. The information concerning instruments and their uses, having been so often repeated, seems superflous; the same may be said of many of the Geometrical problems; yet it is true that the book would be incomplete without them. The general principles of projections and their applications, have been so concisely and fully expounded by Church, Davies, Binn, Warren, Adhemar, and others, as to leave nothing to be desired in that direction, unless it be some new or extended application. The rules given on page 144 for *graduating* the shade on an oblique *plane*, are opposed to the theory of reflected rays from plane surfaces, and mislead the student by giving to one plane the appearance of two or more, intersecting at different angles. We notice, also, a slight error on page 192, concerning the datum surface for levels referred to the sea —It should be *mean low* tide instead of "the *lowest level of tide water*," and distances measured vertically *below* this surface are not generally distinguished from those above by the opposite algebraic signs + and —, but by the shore or water line. They are expressed in feet and fathoms, and are positive.

The hachure system of representing topographical features we have never considered of any practical use for indicating degrees of slope, as its value is entirely dependent upon the accuracy and skill of the draughtsman and engraver, of which the reader can know nothing, nor can he determine frequently whether any attempt has even been made to apply the rules for the shade of slopes. As it is, however, a recognized system, it must enter into such a work, but should only be used for relief maps and not for accurate slope representations. For this latter purpose, the *contour* system is infinitely better, and its applications of much practical value. The author does not even use the term *contour*, much less define it, but speaks of it as the horizontal curve (it may be a straight line). The codes of conventional signs and tints are also incomplete. There is one important division of Industrial Drawing which is not mentioned in this treatise, and that is its application to the Industrial Art, now attracting so much attention, and without which no work with this title can be considered complete.

With these exceptions, we believe the work will compare favorably with its compeers, and be found useful by all desiring to study the Art of "Industrial Drawing."

ON THE DIRECT PROCESS OF MAKING WROUGHT IRON AND STEEL[1].

By Chas. M. Du Puy, C. E.

It is scarcely necessary, at this late day, and before this Institute, to explain the difference between the "direct" and the "indirect" methods of producing iron that can be forged. Suffice to say that by the primitive "direct" method, 400 or 500 lbs. of ore, mingled with charcoal, are subjected to the action of blast for 3 or 4 hours, when it becomes imperfectly matted together, and is transferred to the hammer; where its earthy impurities, being melted, are removed by pressure. This process secures a high grade of iron, at the cost of about 300 bushels of charcoal and great waste of ore to the ton of iron.

The "indirect" method treats large masses of ore, carbon and fluxes in the blast furnace. Deoxidization takes place early in the first stage, but afterwards under the action of a powerful blast the metal and metalloids are all mingled, and 3 to 5 per cent. of carbon is incorporated. The earthy impurities are then mainly separated by specific gravity and tapped off, still the pig iron may be said to be a compound of iron, carbon, silica and other substances which require a second melting, and laborious manipulation, to purify the metal for forging or rolling.

To improve and cheapen iron by the "direct" method, has occupied the attention, and baffled the efforts, of many earnest men for three-quarters of a century. The devices have been numerous. In 1791, Samuel Lucas patented a process for reducing ores with carbon in air-tight pots. In 1794, Mushet forged iron which he had carefully reduced, away from the atmosphere, and brought to the pasty state in a crucible. Others, later, passed over the same ground, for the superiority of the metal when reduced and welded, uncontaminated by the oxygen of the blast, or furnace gases, had been observed, and stimulated to further effort.

The reduction of ores in crude clay pots, it is likely, has been known to the people of Asia for a thousand years, if indeed it was not almost cotemporary with the earliest manufacture of iron, for it would seem to be one of the simplest ways of producing metal in small quantities

[1] A paper read at the meeting of the Franklin Institute, Oct. 17th, 1877.

and of superior quality. While ordinary Wootz was usually made first into iron in small blast furnaces with light pressure, and then melted again in small pots, it is not unlikely that the famous sword-blades of Damascus, and celebrated scimitars described by Alexander Burnes in his journey to Cabool—where one was shown him that was valued at 5000 rupees—were the product of ore first deoxidized and imperfectly welded or matted together in crudely made clay pots, and then, after being hammered, again melted into a more superior Wootz in other clay pots.

A fresh pot, however, for every operation, even of the rudest and cheapest manufacture, was of course too expensive for any very extended use, and a half century ago, devices began to be suggested in which the ore could be deoxidized in a close vessel, and then emptied into a balling hearth, and so the vessel be used over and over again. To that end, the files of our own patent office, and those of Europe, exhibit a variety of inventions and processes, dating up to the present time, but they may be all divided into three classes:

1. Close retorts or crucibles of various shapes and sizes, heated from the outside, being substantially the "*Air-tight Pots,*" patented by Lucas.

2. Tables of refractory material, heated from above and below, on which the ore and carbon were placed and stirred, and finally transferred to a balling hearth.

3. Revolving cylinders, containing ore and carbon, and heated from the outside, or within.

In the first two classes, deoxidization was *supposed* to be completely accomplished in the first operation, and the balling was done in a second furnace, but in the *last* class, Dr. Siemens' invention, the rotary cylinder, the gas from the producers is poured into the *inside* of the cylinder, until not only complete deoxidization is effected, but until the metal in the pasty state may be divided into balls, for removal to the hammer.

Many years since, being convinced by a long series of experiments that iron reduced from ore in close pots, and out of reach of external oxidizing influences, was of superior quality, I tested many devices for placing this mode of manufacture on a practical working scale.

In the course of these experiments I found that ore and carbon are such perfect non-conductors, that the highest heat penetrates from the outside very slowly through a thickness of about 3 inches of this substance, and that to add 2 or 3 inches thickness of crucible or

containing vessel, practically defeats complete reduction in a sufficiently speedy time to be successful, and has been the main cause of the failure of this class of inventions.

Although the authorities generally give us the "*cherry red*" and the "*bright cherry red*" heats as the best condition for deoxidization of iron ores, yet I have found these heats wholly unfitted for complete reduction, in such periods of time and at such cost, as to make the manufacture commercially profitable. A thorough reduction of any considerable mass of iron ore, with heat penetrating from the *outside*, in the space of 5 or 6 hours, is so closely allied to a *white welding heat*, that it seems impossible to separate it; and to deoxidize ore only $2\frac{1}{2}$ to 3 inches in thickness, within that time, I find most profitable to drive the furnace up gradually to a high welding heat, at which, finally, it is penetrated through and through, passing into the pasty state and settling down into a metallic mass, interspersed with liquid slag.

Now a crucible or pot of any refractory material, sufficient to withstand a heat from the outside that would bring the $2\frac{1}{2}$ inches of ore to iron in the pasty state, in any considerable quantity for but a very few operations, would be costly at first, and costly in frequent renewals. Beside this, any material of which it might be composed, would soften at the pasty state of the iron, and become more or less incorporated with the metal in the difficult operation of withdrawing it, and so the iron would be seriously deteriorated.

To secure the advantages of the "*close pot*," it became evident that some substance should compose it, that should withstand the high welding heat, and be homogeneous with the metal, and, finally, when its work was done, and the ore changed to metal, would *weld up with it*.

In this dilemma, after testing various materials, I conceived the idea of using *thin sheet iron* as *an encasement, or canister*, having found by experiment that it would resist a high heat for several hours. These sheet iron vessels, filled with ore and carbon, during several years, were tried, of all sizes and shapes, and in almost every conceivable furnace. It was found that superior iron could be produced in these canisters in 7 or 8 hours, but the *yield* was *unsatisfactory*, when over 5 inches in thickness, owing to a failure of thorough reduction, and of that diameter, the cost for sheet iron was *too large in proportion* to the iron obtained.

Still believing that the process could be made practical, and the metal be produced in from 4 to 6 hours at a low cost, the canisters were placed on a coke bottom, in a reverberatory furnace, which was

driven with blast, to produce an outward pressure—although the coke kept the bottoms heated, which otherwise would have become chilled, yet it was found impossible to increase the size of the canisters, as the heat would not penetrate more than 5 inches thickness to reduce and consolidate the ore to metal, in a reasonably economical period of time.

Finally, the canisters were made *disk* shape, that is to say, a cylinder of 6 inches diameter was placed inside of one about 16 inches diameter, and a bottom being provided between them, the ore and carbon were filled within the annular space, leaving the space within the smaller cylinder open, thus making a ring of the ore mixture, so that when the canisters were placed on end, in the furnace, on the coke bottom, the heat could penetrate from the inside as well as the outer surfaces. By this arrangement these cylinders can be two or three feet high, and yet all the ore can be penetrated with heat traveling not more than $2\frac{1}{2}$ inches.

Although this improvement was found highly advantageous for rapid reduction, yet it was not fully satisfactory, owing to the oxidizing gases of the furnace, which still wasted metal by reoxidation; for I would remark here, that however perfect it is possible to make a *reducing heat*, in a reverberatory furnace, still the combustion necessary to produce a *high* heat, is more or less *oxidizing* to the ore in its sensitive transition condition to metal.

As it is estimated that every pound of silica ordinarily carries with it about three pounds of iron, it occurred to me, to create for the silica a greater affinity than it has for the metal, by mingling alkalies, and to so proportion them, that the glass thereby produced by not combining with it, should not only save the iron, but that it should be further utilized by forming particles of glazing or varnishing material, covering the little particles of metal as formed, and thus protect them from furnace reoxidization. This step proved effective. Now the alkalies in quantity, and kind, having been determined by an analysis of the ore, they are mingled with it along with the carbon, and are all pulverized together, by being thrown, in the proper proportion, into an ordinary *Chilian mill*, such as is used in Western rolling mills for grinding the "*fix*" and from thence shoveled at once into the canisters, and charged into the furnace.

The carbon for deoxidizing may be either charcoal, or coke from washed bituminous coal, or washed anthracite dust. The iron, with either kind of carbon, is thoroughly reduced, and under the hammer and

rolls, or in the steel pot, I have *yet observed* no difference in the product. This mode of working must ultimately afford a market for the mountains of anthracite coal dust now wasted in our coal regions.

There are four ways of working this process, according to the purpose for which the metal is desired:

1. If it is desired to make steel, the canisters, filled as described, are charged on end into the furnace on a layer of coke, a few inches in thickness, so as to allow the heat to penetrate from the bottom, as well as sides and top. They are usually placed 7 or 8 inches apart to secure a radiation of heat between them.

In the course of from five to seven hours, according to the strength of the heat, the ore will be reduced from its oxide and settle down into almost a solid metallic mass, so firm as to be separated and broken with great difficulty, even in its highly heated state in the furnace. In this solidified condition it is removed and hammered, or thrown into the squeezer and rolled to muck-bar, at this one first heat. It is then cut up, reheated and piled, with the usual loss of 8 to 10 per cent. of ordinary piled iron. This stock is then fitted for the steel pot, producing all grades of steel, up to the highest, without mixing with other stock, but by simply varying the carbon.

2. The caked metal may, if preferred, be taken in its heated state to the Siemens open hearth, or other highly heated furnace, and there quickly melted with or without the usual carbonizing bath of pig and spiegel. In the condition of white heat, in which it is charged into this last furnace, it is admirably adapted for a rapid conversion to steel in large quantities, and at great economy of fuel.

3. The metal, when reduced, I have melted down in the same furnace and carbonized with pig iron. In operating the entire process in one furnace, the product may be brought out as either iron or steel at pleasure, by varying the carbon introduced at or before the time of melting.

If iron is required, as soon as the metal has separated from its impurities, precipitated to the bottom and covered with slag, the operator at once rolls it up in balls and subjects it to the hammer or squeezer. No excessive labor is required in stirring the metal, as is required to *decarbonize pig iron*, for this metal has *been deoxidized* without labor, simply by the chemical action of heat on the material; and there is no *excess of carbon to eliminate.* It has also separated itself, in the liquid state, by specific gravity, from its metalloids altogether, without the aid of physical labor. Finally, as it lies at

the bottom of the furnace, it is incorporated with *just sufficient* carbon as is needed by the operator to produce the grade of metal required.

I will remark here, that the iron produced by this process, in cakes of metal, is generally *red short in its nature.* It does not matter with how much carbon the ore may have been mingled, still it refuses to receive more carbon than to produce deoxidization, until it is about to pass to the pasty state and is brought almost to a melting condition.

This "red short" tendency, as the following analysis proves, proceeds from the *purity* of the metal, and not from an alloy of sulphur or other deleterious substances.

Believing that the red short could be cured by alloying *red short* and *cold short*, or *phosphoreted ores together*, I found, by a number of working tests, the product *still red short.* I then tried ores charged with *phosphorus alone*, which, if worked alone in the old processes, would have given highly "*cold short*" metal, but still my product was "*red short.*"

I then incorporated cast iron roll turnings with the mixture, and found that the alloy of carbon with the metal, in the pasty state, and as it become melted, lessened in a very marked degree the red shortness under the hammer. After that I introduced pig iron at the melting stage, observing again the same marked improvement in the metal under the hammer. So that I have finally come to the conclusion, by practical tests, that when the metal is alloyed with sufficient carbon, the red shortness may be removed.

Dr. Siemens, in his late address before the Iron and Steel Association, in their meeting at New Castle, ascribes this "*red shortness*" to "*slag shortness*," as he terms it, because, on repeated pilings and reheating, this tendency is gradually removed. My own experience is different. I have not been able to remove the "red short" by repeated heating and piling, but find I can only remove it by alloying the metal with carbon.

4. Another method I have adopted in working this metal, is to take the cakes as reduced, at their white heat, and *sink* them in the forge fire. The quality of the metal is thereby highly improved in toughness, as is illustrated by samples of sheet iron here exhibited. By throwing the heated metal into the forge fire in this way, they sink, and are taken to the hammer in a half hour, with half the expenditure, both of fuel and labor, that is ordinarily required in sinking scrap in the forge fire. Still, even in the forge fire, "*red*

shortness" is *not cured.* This is accounted for by the rapidity of passing the metal before the tuyere in the melted state, which does not give time for the absorption of carbon, and, although improved in every other respect, it comes from the forge fire *nearly as red short* as when it was thrown into it. It requires the longer contact with carbon than is there so briefly allowed.

"Red short," produced, as it is, by purity of the metal, and not from sulphur, is not prejudicial in melting for steel purposes, for in all cases the steel is of the finest quality, ranking with that made from the best *Swedish brands of iron*, as the samples here exhibited prove. For many uses of iron, too, a strong red short tendency is not only unobjectionable, but is required. Still, for neutral iron, the *red shortness* must be cured, and this can be done at pleasure with an alloy of carbon *in the melted state.*

The purity of iron made by the *direct* processes, has always been a subject of remark, in contrast with that which is made by the *indirect* methods. Even particles of iron, *taken from a mass* of slag highly charged with phosphorus, on being analyzed, have been found of extreme purity.

It will be observed, by the analysis of Dr. Wuth of the iron made by my process, that about three-quarters of the phosphorus have been eliminated from the Republic ore which was used, and which he analyzed. A correct solution as to how the phosphorus is eliminated by the direct processes, when it *clings so closely* to *pig iron* made from *phosphoretic ores*, and *cannot* be eradicated from the *Bessemer converter*, when phosphoretic pig is used, is now occupying the attention of the ablest metallurgists of this country and Europe.

The best theory I am able to suggest, is that as the phosphorus melts at a low heat, and the metalloids also melt, when combined with suitable fluxes, at a much lower heat than the metal, that the phosphorus becomes incorporated with the glassy slag of the metalloids, and never afterwards leaves it, and that finally, when the metal is pushed to the melting condition, in the quiet heat of "the open hearth" furnace, the phosphorus floats with the slag, and cannot contaminate the metal in this *quiet* heat, as it does under the intensely violent *mixing* action of the blast in the Bessemer "converter," or in the blast furnace.

It will be observed that a triple chemical operation begins to take place at once, from the moment the canisters are charged into the furnace.

First. The oxygen of the ore combines with the carbon, passing off as carbonic oxide.

Second. The silica and alumina combine with alkalies introduced, and form the glazing material which cover the particles of newly-made metal, effectually sealing these particles from reoxidation from the furnace gases.

Third. The phosphorus melts into this glass, and passes off with it as a slag, *not contaminating the iron.*

The average of 14 analyses of *the ore* from the Republic Mine of the Lake Superior district, gives:

Metallic iron, ...	68·48
Phosphorus, ...	·053
Silica, ...	2·07

The analysis of reheated iron from the same ore made by my process, as given by Dr. Otto Wuth, of Pittsburg, is as follows:

Carbon, ...	0·042
Silicon, ...	0·021
Sulphur, ...	0·032
Phosphorus, ...	0·016
Slag, ...	0·185
Iron, ...	99·700

A comparison of the foregoing analysis with the analysis of some of the well known and most superior Swedish and Russian brands, is herewith given, showing a very marked resemblance:

	Dupuy.	From Dannemora Magnetic Ore.				From Russian.	
		L	Sykes. O O	J B	K	CC ND	K3 KB
Carbon,	0·042	0·087	0·054	0·087	0·386	0·272	0·340
Silicon,	0·021	0·115	0·028	0·056	0·252	0·062	trace.
Sulphur,	0·032	0·220	0·055	0·632	0·757	0·234	00·66
Phosphorus,	0·016	0·034	trace.	0·005	trace.	....	....
Manganese,	....	....	trace.	....	trace.	0·020	trace.
Arsenic,	....	trace.	....	trace.	....	trace.	....
Slag,	0·185	....	....	....	....	....	....
Iron,	99·700	99·544	99·863	99·220	98·605	99·412	99·594

I come now to a consideration of the successful working of this process on a profitable commercial scale.

The ore, carbon, and fluxes, as has been proved by working, may all be ground together and charged into the canisters at an outside cost of 40 cents per ton of ore; when systematized, 30 cents per ton will be sufficient.

Canisters of No. 26 sheet iron, 15 inches outside diameter, and 13 inches high, with a tube 6 inches diameter passing through and through in the centre, including top and bottom, will weigh 6 lbs. They will hold 116 lbs. each of 67 per cent. ore, beside the carbon and fluxes. This has been the size that has generally been used, and each canister will yield from 75 to 80 per cent. of the metallic iron, including the 6 lbs. of sheet iron canister.

It is believed that in a furnace adapted to the purpose, the canisters may be made 16 inches diameter and 38 inches high, or even larger, and placed 6 or 8 inches apart all over the floor of a large reverberatory furnace.

Suppose a furnace is constructed 10 by 15 ft. inside capacity, to hold 5 rows of these canisters one way, with 7 canisters in the other, placed 8 inches apart and 8 inches from the furnace walls, then the furnace would hold 35 canisters, each containing about 400 lbs. of ore. They would be reduced in 6 to 7 hours, but say 3 charges of the furnace were made in 24 hours. Each canister of 400 lbs. of ore, yielding 80 per cent., or 230 pounds of the metallic iron hammered or squeezed, would give 8000 lbs. of iron at a charge, or 24,000 lbs. of muck-bar every 24 hours. I have found either natural draft or blast may be used.

The cost for canisters—11 to the ton of iron, say 15 lbs. each, would be about 186 lbs. of common sheet iron to the ton of product, which would include all kinds of defective sheets made at a mill, and also include the making of canisters—which is very simple, as may be seen by the sample exhibited—not exceeding in all, $5 to $6 per ton for the iron produced, and probably still less. This cost of canister per ton equals about the cost of breaking pig and puddling it in the old method, with the additional advantage that the work is reduced to extreme simplicity by the use of unskilled labor, and is in strong contrast with the excessive and laborious manipulation in decarbonizing pig iron in the difficult operation of puddling.

This process is very economical in welding together scrap. Ordinary scrap iron may have been so often worked over, at high heats, as to be exhausted of its cinder, such as the scrap from wrought iron

pipe, or it may be the thin waste ends from sheet iron, or of any other quality of iron subject to excessive waste in the ordinary working. I charge it all, whatever it may be, with the ore and carbon in the canisters, and it is *then protected* from oxidizing, being thoroughly enveloped with the carbon, until the whole mass of scrap and ore is consolidated and taken to the hammer. Ordinarily, light scrap is very largely wasted by oxidation in the reverberatory *scrap furnace* and *forge fire*, ranging in loss all the way up from 15 to 20 per cent. By this process I get very nearly the entire weight back.

Having given the cost of grinding the mixture, of canisters, and filling them, and shown by the samples that reduction may be effected by anthracite coal-dust, or other cheap and wasted fuel, it remains to state that the cost for heating the reverberatory furnace will be about $2 per ton of iron, as near as can be approximated at the present prices of fuel; and that the labor in charging and discharging from the furnace and rolling to muck, will not exceed $3 to $4 per ton, including cost of running machinery.

The following is an estimate for canisters of reduced metal, transferred white-hot to the "Open Hearth Furnace" sufficient for 1 ton of steel stock:

$1\frac{3}{4}$ tons rich ore, at $3.50, or . . . $2\frac{3}{4}$ tons impure ore to be separated, at $2.25,	$6 13
Anthracite coal dust, for deoxidizing, $\frac{1}{2}$ ton, at $1.50,	0 75
Crushing ore, coal and fluxes, mixing and filling canisters by automatic machinery, . .	1 00
Gas for reducing, ...	2 00
Canisters, 180 lbs. sheet iron, including making, at $3\frac{1}{4}$ cents per lb., ...	5 85
Labor to the ton, ...	1 00
Fluxes, ...	0 50
For one ton of steel stock transferred to the open hearth, ...	$17 23
For muck-bar, add cost of hammering or squeezing and rolling, say	1 00
	$18 23

To both estimates must be added, the usual items for wear and tear and general expenses.

Summing up all the data given, it will be found that muck-bar may be produced for $8 to $10 per ton above the cost of pig iron; that it will rank with the highest grades of wrought iron for special pur-

STATEMENT OF IRON MADE DIRECT FROM THE ORE, BY DU PUY'S DIRECT PROCESS, MANUFACTURED AT PITTSBURG AND VICINITY.

Date of Charge, 1877.	Kind of Ore used.	Kind of Furnace used.	At what Mill manufactured.	Number of Canisters in charge.	Outside diameter of each, in inches.	Inside diameter of each, in inches.	Height of each, in inches.	Weight of each Canister, in pounds.	Weight of Ore and Canister contained in the charge, in pounds.	Weight of Metallic Iron composing the Ore & Canister in the Charge.	Weight of Bloom from charge.	Weight of Muck-bar from the charge.	Per Cent. of yield from the metal contained.	Kind of Carbon Used.	Gas draft or Blast.	REMARKS.
Jan. 25.	"Republic."	Siemens' Heating.	Union Iron Mills, Pittsburg.	3	$15\frac{1}{4}$	$6\frac{1}{2}$	14	9	375	260		218	84	Charcoal.	Gas.	Reduced in 6 hrs.
" 29.	"	"	" "	2	$15\frac{1}{4}$	$6\frac{1}{2}$	$15\frac{1}{2}$	9	270	187		160	86	"	"	" " 7 "
" 29.	"	"	" "	2	$15\frac{1}{4}$	$6\frac{1}{2}$	$15\frac{1}{2}$	9	270	187		145	77	"	"	" " 7 "
Mar. 21.	"	"	" "	12	14	7	$13\frac{1}{2}$	$7\frac{1}{2}$	966	676		530	78	"	"	" " $5\frac{1}{2}$ "
April 6.	"	Ordinary Heating.	Anderson Steel Works Pittsburg.	3	14	7	14	7	261	181	140		77	"	Blast.	" " 6 "
" 6.	"	"	" "	3	14	7	14	7	261	181	130		72	"	"	" " 6 "
" 10.	"	"	" "	3	14	7	14	7	291	201	161		80	Anthracite.	"	" " $6\frac{1}{3}$ "
" 10.	"	"	" "	3	14	7	14	7	286	198	161		81	Coke.	"	" " $6\frac{1}{3}$ "
July 18.	"Chateaugay."	"	Crescent Steel Works.	1	15	$6\frac{1}{2}$	14	$6\frac{3}{8}$	91	63	48		77	Charcoal.	"	" " $7\frac{1}{2}$ "
Oct. 9.	"Iron Mount."	Puddling.	W. D. Wood & Co., McKeesport.	3	15	$6\frac{1}{2}$	13	6	333	229	163		71	Coke.	"	" " 10 "
" 9.	Penn. "Pipe" or Limonite.	"	" "	3	15	$6\frac{1}{2}$	13	6	282	181	156		86	"	"	" " 8 "
" 11.	"Iron Mount."	"	" "	3	15	$6\frac{1}{2}$	13	6	337	231	169		73	"	"	Transferred hot to forge-fire, then hammered & weighed. Reduced in 10 hours.

NOTE.—The Mitaic Iron in the Republic, Chateaugay and Iron Mountain Ores is averaged at 67 per cent., and 62 per cent. for the Limonite or Pipe, which last was roasted. The time required for reducing, varied with the intensity of the heat. It is believed 5 hours will be found sufficient, with the experience obtained by continuous working.

poses; and that the plant is so simple and inexpensive, as to make a large *reduction* in the interest account of all iron works. Besides this, it will be found that the process is so greatly under the control of the operator, as to enable him to make such mixtures as to produce the *exact quality* of iron or steel desired, not being subject to the irregularity of the blast furnace, which often, as is well known, for days together, gives a run of undesirable metal, baffling the utmost skill of the manager to change it. This direct process, in a word, reduces the exact results of the laboratory to a large and intelligent practical working basis for the manufacture of iron and steel; and, as such, I respectfully submit it to the impartial and unprejudicial consideration of the members of this Institute.

Relative Cost of Water and Steam Powers.—The cost of the water power equipment at Lowell, was, for canals and dams, $100, and for wheels, etc., another $100, per horse power. But this, as a first experiment, was more costly than a similar equipment need be. At Saco, the expense incurred was $175 per horse power; but at a later period, for turbines with high heads, the expense would be less. A construction and equipment, solidly carried out, with the latest improvement in wheels, would not cost over $200 per horse power, and would, under favorable circumstances, cost less. An estimate at Penobscot, was for $112.50 per horse power. If the construction be with wooden dams, and the equipment with lower grade wheels, then the cost would be about $50 per horse power; and although the construction would be less permanent than the more solid, it would outlast any steam apparatus. On the other hand, Fall River estimates of steam equipment, exclusive of foundations and engine houses, run from $100 to $115 per horse power. A Boston authority gives $115 per horse power for nominal 300 horse power and upward, inclusive of foundations and masonry. Similarly, a Portland authority places it at $100 per horse power. The actual cost of steam equipment in the water works of various cities of the United States, varies from $150 to $300 per horse power.

As to the cost of work done, it appears that in Philadelphia, in 1867, the cost of raising water by water power, was only 2 cents per 1,000,000 gallon feet; whereas the cost by steam power was in four cities $8\frac{3}{10}$, $11\frac{1}{10}$, $19\frac{1}{10}$ and $29\frac{2}{10}$ cents, with coal at $5.50 per ton.—*The Water Power, Maine.*

ON A NEW TYPE OF STEAM ENGINE, THEORETICALLY CAPABLE OF UTILIZING THE FULL MECHANICAL EQUIVALENT OF HEAT-ENERGY, AND ON SOME POINTS IN THEORY INDICATING ITS PRACTICABILITY.

Presented at the Nashville meeting of the American Association for the Advancement of Science, 1877.

By Prof. ROBERT H. THURSTON, Vice-President.

(Continued from Vol. lxxiv, p. 325.)

XXI.—Were it possible to conduct this operation of re-working the rejected heat by passing it through the first cylinder again, instead of being compelled to use additional engines, it would be decidedly more satisfactory than the use of the Binary class of engines. We may naturally next consider the possibility of returning to the reservoir all heat rejected in engines using vapors, as of water, as their working fluids. As the regenerator system is inapplicable here, it is necessary to secure the return of that unutilized heat by restoring to the reservoir all exhausted gas or liquid, or both, without seeking to remove from them and to restore separately the heat with which they are charged. Fortunately, the conditions which make the use of the regenerator system impracticable, are favorable to the adoption of the expedient which has been described as characterizing the operation of engines of Type B.

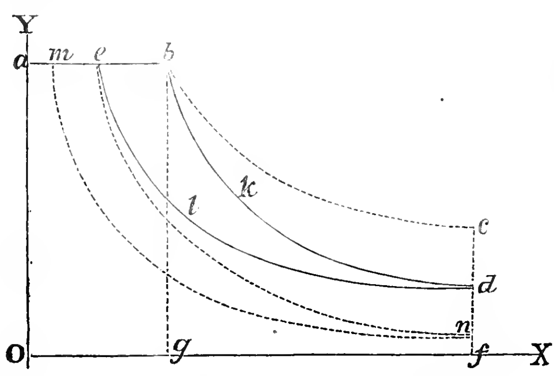
As has been seen, the expansion of steam doing work results in the condensation of a portion of the vapor. The weight of steam condensed bears a proportion to the weight of steam supplied, which is greater as the work done by expanding that steam becomes a greater proportion of the mechanical equivalent of the thermal contents of the steam when supplied to the working cylinder.

Suppose the expansion to be carried so far that one-half of the vapor becomes liquid. Imagine the water of condensation separated from the uncondensed vapor, and the two masses returned to the boiler separately by compressing pumps. The return of the water would involve the expenditure of an amount of work measured by the product of the volume of that water into the difference of pressures in the boiler and in the receiver into which the exhaust has been discharged. The return of the uncondensed steam would involve

not only the return of the charge of heat contained in that steam, but also the return of all the energy which the vapor had yielded during its expansion; since an equivalent amount of heat would be generated by its recompression to boiler pressure.

Under the conditions now assumed, it is evident that only that portion of the heat entering the engine which is surrendered by the condensation of steam doing work can be utilized. It is also evident that, in this form of engine, no heat can be lost; and, consequently, that the engine of Type B, which is operated as just indicated, will have yielded the exact equivalent of the net amount of heat expended upon it. All heat rejected from the working cylinder, unutilized, being returned to the boiler, there to form "a basis on which to pile up a new stock of utilizable energy," the engine is a "perfect engine" in a broader sense than that adopted by Carnot. It is further evident, that perfect efficiency is given for all ranges of temperature, and that what working fluid shall be adopted and what temperatures shall be chosen, will be determined simply by practical conditions to be ascertained by experiment.

The work done in restoring the water of condensation to the boiler being so small in amount that it may be neglected, the ratio of the total work done in restoring rejected heat to the work done by the steam on the piston will be the ratio of the weight of steam restored to the boiler of the engine to that supplied to the working cylinder at each stroke. Altering an engine of the common type, having an efficiency of 0·25, into an engine of Type B, the quantities of work done during expansion and during compression will have the ratio, nearly, of 1 : (1 — 0·25) = 0·75.



The indicator diagram of our new engine will be similar to that shown in the accompanying figure, in which the ordinates of the curve measure the pressures, and the abscissæ are proportional to

the volumes of the expanding fluid. The steam expands from the volume $g\ O$ to the volume $f\ O$, when doing work, and from the pressure $O\ a$ or $b\ g$ to the pressure $c\ f$, when expanding according to Boyle's law. Doing work, however, the gradual condensation of the fluid reduces the pressure during expansion, and the line becomes $b\ k\ d$, instead of $b\ c$. When the attempt is made to restore the rejected fluid to the boiler, the compression would naturally cause the line $d\ k\ b$ to be retraced; but having removed the water of condensation from the engine separately, it cannot add, by its re-evaporation, to the tension of the steam under compression, and the latter must behave more nearly like a perfect gas, causing the line to take the direction $d\ l\ e$. The net result is the production of mechanical energy represented by the area $e\ b\ k\ d\ l\ e$, and the expenditure of an equivalent amount of heat energy, plus the amount of energy required to return the water of condensation to the boiler. Had, in this case, the steam been cut off at an earlier point in the stroke, as at e, the area $e\ n\ m$ would have represented the quantity of heat transformed into work. It is evident, that the more the steam is expanded, the greater will be the proportion of steam condensed, and the less the amount remaining to be compressed to boiler pressure, and the less the weight of steam required to be supplied to the engine per unit of work done. It follows that, to secure an engine combining high efficiency with small volume, it will be advisable to employ steam of high pressure, and to expand it as much as may be found practicable. The new type of engine can, probably, only supersede the common form when engineers can employ steam of very high pressure, and adopt much greater range of expansion than is now usual. Great velocity of piston and high speed of rotation are also essential in the attempt to make this revolution in steam engine construction a success.

XXII.—The term efficiency requires more accurate definition than is usually given it in works treating of heat engines. There are several distinct quantities to which the term is often applied. The *efficiency of the fluid*, by which should be understood the ratio of the quantity of work done by the working substance to the mechanical equivalent of its thermal contents at the instant of entering the cylinder of the engine, and which, measured by the quantity $\frac{Q - Q'}{Q} = E$, is often confounded with the *efficiency of the engine*,

which latter is the ratio of work of the engine during a given interval of time to the mechanical equivalent of the heat supplied to the engine in that time. The *efficiency of the boiler* is the ratio of heat delivered from the boiler in dry steam to the amount of heat developed in its furnace by the combustion of fuel. The *efficiency of the furnace* is the ratio of the amount of heat rendered utilizable by transfer to a boiler, by that furnace, to the amount of heat generated by the perfect combustion of the fuel supplied. The *efficiency of the engine* is also often taken as the efficiency of the whole combination of engine, with its fluid and with boiler and furnace working together. This latter is also often confounded with the efficiency of the fluid as well as with the efficiency of the engine proper. It is generally assumed that the theoretical efficiency of the steam engine, including its boiler, is limited by the efficiency of the fluid, and that, for example, the efficiency of an engine working between the limits of 800° and 600° on the absolute scale can have no greater efficiency than that measuring the efficiency of the fluid =, say, 0·25. That this is not the fact is seen when it is remembered that our ordinary calculation of the efficiency of the fluid takes no note of the temperature of the fluid supplied to the reservoir or of the method of disposal of rejected heat, which, as we have seen, is usually partly saved, and may be wholly restored.

Assume the limits of temperature and pressure of two engines to be the same, the upper limit being 90 pounds absolute pressure and the temperature 320° F., or 180° C., and the lower limit 2 pounds and 126·27° F., or 52·37° C., the working fluid to be steam, and one engine to be of the ordinary type, the other of the new type. Let both engines expand completely from the upper to the lower limit. First determine the value of $\frac{Q - Q'}{Q} = E$ for the common engine, taking Q as the net amount of heat supplied to each pound of steam by the fuel in the boiler, and Q' as the quantity rejected from the cylinder and discharged from the engine, assuming no losses to occur by conduction, radiation, or friction.

E is evidently the efficiency of engine and boiler working together, and its estimation should afford a basis for the calculation of the weight of steam required by the engine, and of water to be fed to the boiler. The efficiency of the furnace and calorific value of the fuel being known, the weight of fuel may then be calculated.

Taking the feed water into the boiler at a temperature of 110° F., which is a very usual temperature of feed, the total heat of steam supplied to the engine at a pressure of 90 pounds per square inch above a vacuum will be $1211{\cdot}5 - 110 = 1101{\cdot}5$. The thermal contents of each pound of steam rejected from the cylinder at 2 pounds pressure, the temperature being 126·27, will be, if reckoned from the original temperature of feed, $1152{\cdot}5 - 110 = 1042{\cdot}5$. The heat wasted with each pound of water so rejected, will be $126{\cdot}27 - 110 = 16{\cdot}27$ thermal units.

The actual weights of steam and of the water rejected, per pound of steam supplied to the engine, may be readily calculated. It has been shown by Rankine that steam, expanding under the assumed conditions, and condensing, as it does, in a non-conducting vessel, preserves a relation of volumes and pressures which may be approximately expressed by an equation of the form $P\ V^x = C$, in which the exponent of the quantity V has a value exceeding unity. Rankine stated this value to be about 1·1111+; but it has been since determined by Zeuner to be more nearly 1·333+, which latter value will be taken as correct. It is confirmed by Cazin and Hirn.[1] The volume of one pound of steam at the temperature and pressure at which it enters our steam cylinder, is 4·72 cubic feet. The value of C is, therefore, $P\ V^{\frac{4}{3}} = C = 90 \times 144 \times \overline{4{\cdot}72}^{\frac{4}{3}} = 102{\cdot}611$. The volume of steam exhausted from the cylinder—expansion being taken to have been carried so far that the pressure at the opening of the exhaust valve is 2 pounds per square inch—must be $V = \overline{C \div P}^{\frac{3}{4}} = (102{\cdot}611 \div 2 \times 144)^{\frac{3}{4}} = 76{\cdot}53$. But the volume of 1 pound of steam at this pressure is 172·4 cubic feet. The quantity of uncondensed steam rejected from the cylinder, per pound of steam supplied, is, therefore, $76{\cdot}534 \div 172{\cdot}4 = 0{\cdot}444$ pound. The weight of water rejected is $(172{\cdot}4 - 76{\cdot}5) \div 172{\cdot}4 = 0{\cdot}556$ pound. The steam carries with it $1042{\cdot}5 \times 0{\cdot}444 = 462{\cdot}85$ thermal units, and the water loses $16{\cdot}27 \times 0{\cdot}556 = 9{\cdot}05$ units. The sum 471·90 units, is

[1] McCulloch. This value of x may have been here accepted on insufficient authority, however, as Zenner, in his treatise (French ed., p. 332), makes it 1·135, and Grashof makes it 1·140. Zenner also shows that the value of x is reduced by the addition of water to the steam. Laboulaye still insists, also, on the value 370 kilogrammetres, instead of 424, for Joule's equivalent, which, if correct, would modify the theory somewhat.

the total amount of heat wasted by rejection from the engine. The heat which has been utilized is $1101{\cdot}5 - 471{\cdot}90 = 630{\cdot}6$. The efficiency, E, is $(1101{\cdot}5 - 471{\cdot}9) \div 1101{\cdot}5 = 0{\cdot}57$, or nearly six-tenths.

As has been seen, had the working fluid been a permanent gas, the efficiency would have been one-fourth. The difference illustrates the superiority of the condensable vapor as a medium for conversion ot heat into work. Assuming perfect efficiency, aside from the defect just estimated, this engine should require but $(1{,}980{,}000 \div 1101{\cdot}5 \times 772) \div 0{\cdot}57 = 4{\cdot}09$ pounds of steam, or about two-fifths of a pound of coal per hour and per horse-power. An actual engine, working steam in this manner, usually consumes at least five times this amount. The difference between the estimated theoretical and the actual efficiency, has usually been supposed to be much less, and it has been stated by the writer, as well as by other engineers, that the range left for improvement, by modification of the structure of the common engine, is much less than it is here shown to be.

The direction in which further improvement must take place in the standard type of engine, is plainly that which shall most efficiently check losses by internal condensation and re-evaporation by the transfer of heat to and from the metal of the steam cylinder. The condensation of steam doing work is evidently not a disadvantage, but, on the contrary, a decided advantage.

To secure this vitally important economy, it is advisable to seek some practicable method of lining the cylinder with a non-conducting material.[1] The loss will also be reduced by increasing the speed of rotation and velocity of piston. Where no effectual means can be found of preventing contact of the steam with a good absorbent and conductor of heat, it will be found best to sacrifice some of the efficiency due to the change of state of the vapor, by superheating it and sending it into the cylinder at a temperature considerably exceeding that of saturation. With low steam and slowly moving pistons, it is better to pursue the latter course than to attempt to increase the efficiency of the engine by greater expansion.

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[1] This plan was adopted by Smeaton, in constructing Newcomen engines a century ago. Smeaton used wood on his pistons. Watt tried wood as a material for steam cylinder linings. That material is too perishable at temperatures now common, and no metal has yet been substituted, or even discovered, which answers the same purpose.

Increasing steam pressure and expanding to a greater extent will give theoretically slightly increased economy. Repeating the calculation made above, using as constants the temperature, volumes and pressures of steam entering the cylinder at 250 pounds, and expanding down to the same point, it will be found that the gain in efficiency is but a few per cent. It is not in that direction, therefore, that we are to look for important improvement in the use of the ordinary type of engine. There seems no alternative but to attempt to alter it into an engine of our new Type B, and look for the discovery of an efficient non-conducting lining material which shall enable us to save the, probably, thirty per cent. of heat supplied which is transferred to the condenser by internal condensation and re-evaporation.

XXIII.—The question whether such an engine as that which has here been described as type B can be made practically successful, can only be answered after careful and intelligent experimental investigation. The advantages promised by the results of theoretical investigation, will be greatly modified by conditions unavoidably introduced in the construction and operation of the machine. Some of these conditions may be anticipated, and their effect upon the efficiency and upon the success of the engine in other respects may be indicated in advance. It is even possible that a rough approximation may be made in estimating its real practical value.

The essential requisites of a successful type of engine are: safety; economy; durability; simplicity; compactness, and a moderate first cost.

Safety may always be secured by intelligent design, good material and workmanship, and skilful management. The new type is not especially liable to objection on the score of danger, except so far as it may prove essential to its success to work at exceptionally high pressures; but as pressures of 1000 and 2000 pounds were controlled without accident, forty years ago, by Perkins and by Albans, it is not to be anticipated that danger will necessarily be incurred at pressures far exceeding those in general use to-day, yet far within the limit already attained. The durability of the engine will also be determined by the same conditions as its safety, and is to be assured in the same manner. The actual economy to be secured by its adoption is largely determined by the size which it may be found necessary to give it; for its losses will be almost wholly due to friction. In simplicity, it is not likely to

compete with the common engine, since it must be fitted with some apparatus for compressing the steam to be returned to the boiler. It is not improbable, however, that the new type may be yet given a form in which it may compete nearly as successfully, in this respect, with the ordinary engine as has the compound type of the latter with the older forms.

To determine the probable size of the engine of Type B, it need only be remembered that, as it must expend, in returning to the boiler its unutilized heat, a proportion, $1 - E$, of the power produced at each stroke, it must, when running at the same speed, work off a greater volume of steam in doing the same work, in the proportion $1 \div E : 1$. But the larger engine will be subjected to frictional resistances which will be similarly increased, and this, in turn, will exaggerate the size of engine and the losses of efficiency. Replacing an engine of the old form, having an efficiency of 20 per cent., by an engine of the new type, it will be necessary to either make the latter of five times the piston displacement of the former, per stroke, or to run the new engine at five times the speed of piston of the old. It should be the endeavor to make the change in the last named of the two ways, not only as a matter of economy of first cost, but as a means of reducing losses of pressure by internal condensation and re-evaporation. It is evident that such losses of pressure do not affect the estimated economy of the engine, since, however much heat is thus caused to be rejected from the cylinder, it is all saved and restored. The higher the steam pressure used, and the higher the efficiency due to increase in the amount of heat converted into work, the more favorable do the actual conditions of use become to the new engine.

Assuming an engine of the proposed type to have an estimated efficiency of fluid of 50 per cent., it must be made, at the same piston speed, twice the size of the engine of the common form. To allow for increased frictional and other losses, an addition in enlargement of probably 25 per cent. must be calculated upon. The theoretical cost of the horse-power will be about 5 pounds of steam per hour. The losses of heat by conduction and radiation, which, in the common engine, may be taken as 10 per cent. as a maximum, will become 20 per cent., and will bring up the consumption of steam to 6 pounds per horse-power developed in the cylinder. The resistance due to friction, which may also be taken at 10 per cent., will be doubled also, and this will raise the expenditure of steam to above 7 pounds. We may take

as the probable consumption of heat in such an engine, per hour and per horse power, very nearly 8000 British thermal units. With good boilers, this will call for the combustion of about three-quarters, or four-fifths, of a pound of good fuel—about one-third the amount demanded by the very best engines ever built for transatlantic steamers, and one-quarter as much as is usually consumed with very large marine engines of the now popula compound type. But the advantage to be secured by the adoption of this type becomes greater with higher pressures, and will therefore be likely to appear greater and greater continually. With what would now be thought exceedingly high steam, and with vastly increased piston speeds, such as will almost certainly be adopted in the future, the new type will appear a very much more promising plan than it now does.

The now standard engine drives a steamship across the Atlantic with a consumption of 1000 tons of coal; the new engine should do the same work on 250 tons. It should occupy but little more available space in the ship, but would weigh twice as much unless the piston speed were correspondingly increased. The greater weight of engine would be vastly more than counterbalanced, however, by the reduction of space and weight devoted to boilers and coal-bunkers, to one-third or one-fourth their present capacity. If this type of engine should prove to be available with steam pressures that are soon to be found readily controllable, it is certain that it will be even more advantageous for marine purposes than for use on land, where these reductions of space and weight are of less importance. Even its application to locomotives would not be thought impossible.

XXIV.—Several engines of this type have been planned by the writer, in all of which the rejected heat is returned to the boiler.[1]

Any expert mechanical engineer will readily devise many methods by which the standard forms of steam engine may be modified and converted either into illustrations of this Type B, or into engines of Class 2, in which the rejected heat is very nearly all restored to the boiler. When this possible "engine of the future" is likely to be introduced, if at all, can be scarcely even conjectured. It seems evident that its success is to be secured, if its introduction is attempted,

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[1] The idea first suggested itself to the mind of the writer in 1858-9, when at Brown University, and while designing a peculiar form of "drop cut-off engine," which was designed to work with exceptional economy. The plans then conceived have gradually assumed a different shape, but still embody the essential principles here outlined.

by the adoption of high steam pressures, of great piston speeds, by care and skill in design, by the use of exceptionally excellent materials of construction, and by great perfection of workmanship and intelligence in its management. There seems no tangible obstacle to its introduction; but engineers who have seen the slow progress of the compound engine and of surface condensation in marine construction will anticipate no very rapid progress here.

Experiment and experience will probably lead gradually to the general and safe employment of greatly increased steam pressures and very greatly increased piston speeds, and will ultimately reveal and remove all those difficulties which must invariably be expected to be met here, as in all other attempts to effect radical changes, however important they may be. We are continually learning that the use of steam as a medium for transformation of heat into mechanical energy is more advantageous than it had been supposed. The corrected estimates of the efficiency of the steam engine given above, show it to be capable of far more perfect utilization than generally accepted authorities had supposed possible. It is not improbable that even these estimates give a very inadequate idea of the true efficiency of the perfect steam engine. We know almost nothing of the physical properties of steam which are mostly concerned in its utilization in heat engines at the high pressures which we know are attainable; and it is impossible to say that the modifications of specific heat and of pressures at such high temperatures may not be such that it may prove a vastly more efficient working substance for the heat engine, at such temperatures and pressures, than we are led to consider it from our knowledge of its properties at the now usual working pressures.

Stevens Institute of Technology,
Hoboken, N. J., *April*, 1877.

Addendum.—The probability of the successful adoption of the type of heat engine described in the above paper, is evidently largely dependent: first, upon the correctness of Rankine's or of Zenner's determination of the value of the exponent in Poisson's formula, $P\,V^x = C$; secondly, upon the possibility of obtaining a high value of that exponent in actual work. It is evident, that if Rankine's value, $\frac{10}{9}$, were correct, it would be quite out of the question to expect that an engine can ever be built in which the magnitude of the machine should be so far reduced, in proportion to power

developed, as to insure the success of this plan. If the larger value, $\frac{4}{3}$, is correct, it is equally evident that success is possible, even if not extremely probable, assuming that the process of internal condensation and re-evaporation may be checked.

The writer has received, since the above was written, a statement of the results of experiments upon a quick-running portable engine made by Mr. J. C. Hoadley, to determine the value of the exponent, x. In that instance Mr. H. finds the value of x to be 1·247, or nearly $\frac{5}{4}$, in an engine which was not constructed with any special provision for checking this kind of loss, except so far as it is reduced by high speed of piston and frequent reciprocation.

This may, probably, be taken as another proof of the erroneousness of Rankine's value, and the more probable accuracy of Zenner's, and as indicating the possibility of, at some future time, securing a nearly perfect working of the steam in the cylinder, thus attaining, approximately, the perfect efficiency of the new type of engine.

R. H. T.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxiv, page 269.]

If the Rhenania Chemical Works was willing to sell its two platinum vessels, one of which has been procured only a few years ago, while the other has been in use for twenty-one years, and has undergone repeated repairs at the price of 810 francs per kilo., the account would show a consumption of 0·972 grm. of platinum per 1000 kilos. of sulphuric acid, or an outlay on platinum equal to 1·616 francs, or 1·29 marks (not quite 1·3 d.) per 1000 kilos. of acid at that strength.[1]

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[1] "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

[ii] As regards the question what method of concentration is the more economical, the following information has been received by the editor from P. W. Hofmann, of Wock-

In general the acid at Hautmont, and at Stolberg, was free from nitrogen compounds; if nitrous acid was found on testing with indigo, a little ammonium sulphate was added to the acid in the lead pans, according to the suggestion of Pelouze.

The two firms who exhibited platinum stills at Vienna, were Desmoutis, Quenessen & Co., of Paris, and Johnson & Matthey, of London. The apparatuses differ in certain details. The English firm employ double syphons and cooling worms, whilst the French make use of a long single syphon. The capital which conducts away the weak acid slopes towards the body in the English apparatus, whilst in the Parisian it is bent away in the opposite direction. The English arrangement, by reason of its reflux, yields less weak acid, but at the same time also a smaller quantity of concentrated acid than does the French.

The opinions of manufacturers concerning the stills of the two firms, were upon the whole equally favorable. The English acid makers obtain their platinum stills for convenience' sake generally from London, whilst many Continental manufacturers remain in connection with Desmoutis, Quenessen & Co., on account of the rapidity of transport in case of repairs.

Both the stills exhibited in Vienna, had a syphon of a new construction, one of whose legs, placed within the still, has a lateral aperture at the same level with the heating flues. By means of this arrangement, the acid in the apparatus can never fall below the level of the upper angle of the flue. The sheet platinum is therefore constantly covered by the liquid, whilst on the old principle the workman was not able to observe the level of the acid, and the syphon could run off the contents of the still to such an extent, that the furnace-gases could play over and damage the dry metal.

The arrangement in the apparatus of Desmoutis, Quenessen & Co., was proposed by the author.[1] In order to prevent the evacuation of

[1] R. Hasenclever, *Ber. Chem. Ges.*, vii, 502.

lum. At Dieuze, where 2500 kilos. of sulphuric acid are daily concentrated to 66° B. in glass vessels, the cost per 1000 kilos. is as follows:—

Coal, 200 kilos.,	4 marks
Labor,	3 "
Breakage,	1 "

If the precaution is observed of changing all the retorts every six weeks, whether damaged or not, breakage can be almost entirely avoided, and the cost for glass reduced to about 75-100 of a mark.—A. W. H.

the apparatus below the desired level, the lateral orifice in the syphon is connected with an air-pipe, which plunges in from above. It is thus contrived that the syphon always draws off sulphuric acid from the deepest part of the apparatus, whilst a simple lateral orifice in the syphon, without a tube opening upwards, would, during regular working, produce an influx of sulphuric acid into the syphon at this place. To prevent the acid spurting out during boiling, a funnel with a movable cover is fitted to the top of the air-pipe. If it is wished to empty the apparatus entirely, the aperture of the funnel is closed with a plug, which is not kept by the workman in charge.

In the arrangement adopted by Johnson & Matthey, for the same purpose, a reciprocating cock is introduced into the air-pipe above, so as to allow the apparatus to be emptied. It is probable that the workman will generally close this cock, for when the syphon is run out, he has the trouble of filling it again, before resuming work. He operates then with an arrangement which acts exactly like a common syphon, as when the cock is shut, the lateral orifice does not communicate with the atmosphere.

A. de Hemptinne[1] constructed an apparatus for concentrating sulphuric acid down to 1·84 specific gravity under reduced atmospheric pressure without the use of glass or platinum. The apparatus is said to be in operation near Brussels, but is little employed elsewhere.

Baist and Rœssler, of the Greisheim Chemical Works, employ experimentally a modified platinum apparatus, as patented by Johnson & Matthey. In this arrangement only the lower part of the still which contains the acid, and is exposed to the furnace gases, is made of platinum, the dome being constructed of lead. This apparatus does not cost half as much as an ordinary platinum still, but in practice it requires frequent repairs, since the lead is heated too strongly from below, and is too heavily weighted above by the refrigerating liquid.

Faure & Kessler, sulphuric acid manufacturers, at Clermont-Ferrand (Puy de Dome), have sought to improve the construction of the platinum and lead concentration apparatus. This process is described in a pamphlet, "Notice sur les Appareils a Cuvette pour la Concentration à 66° B. de l'Acide Sulphurique."

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1 A. de Hemptinne, *Dingler's Polyt. Journ.*, ccv. 419; *Wagner's Jahresberichte*, 1876, 243.

The acid is heated in a very flat platinum pan, of about 70 centimetres diameter. Over this pan is a very roomy lead chest, in which is condensed the weak acid which distils over. This construction affords a greater prospect of durability than the dome resting directly upon the pan, and the apparatus is said, in fact, to be capable of working for months without repairs. The inventors give in their pamphlet a comparative scale of cost, and mention as the principal advantages the following:

1. Decrease of first cost in the proportion of 300 to 350 per cent (?).

2. No wear and tear of platinum.

3. Decrease of 90 per cent. of the loss in case of accidental injury to the still.

4. Economy of fuel.

5. Reduction of labor to the extent of 30 to 60 per cent.

6. Total abolition of the stoneware jugs, used for filling the apparatus, and consequently no loss from their breakage.

7. Freedom from danger.

8. Greater regularity.

9. Reduced wear and depreciation of platinum, one-twentieth of ordinary amount. (But see No. 2 above.)

10. Great convenience for repairs.

An apparatus of Faure & Kessler's, costing 15,000 francs, is said to yield in twenty-four hours about 2500 kilos. of sulphuric acid at 66° B. An apparatus of the same power, entirely of platinum, can be had from Desmoutis, Quenessen & Co., for 30,000 francs, even if the platinum costs 1000 francs, and not for 45,000 francs, as assumed in the pamphlet. The first cost, supposing Faure & Kessler's system to hold good, is only reduced 50 per cent.

The advantages Nos. 2 to 10 cannot be taken into consideration: stoneware jugs can be dispensed with in an ordinary apparatus, and the depreciation of the platinum pan must be increased, since in the ordinary construction it is precisely the lower part which suffers, whilst the weight of the dome and syphon remains approximately constant.

[To be continued.]

MUSIC OF THE MOONS.—II.

By Pliny Earle Chase, LL. D.

[Continued from Vol. lxxiv, p. 354.]

The harmonic series, of which Mars and its satellites form a part, seems to have been established before the ring of greatest nebular condensation—the ring of which Earth was the centre—was broken up. In the solar system, as well as in the group of densest planets, the number 3, which represents the uneven harmonics of an organ-pipe, as well as the oscillatory divisions of a linear pendulum, holds a prominent place. For we find, at the outset, the following approximations to important nebular centres:

$3^8 =$	$9^4 =$	6561	6518 =	Neptune's secular aphelion.
3^7		2187	2222	Saturn's secular aphelion.
3^6	9^3	729	735	Cybele.
3^5		243	229	Earth's secular aphelion.
3^4	9^2	81	83	Mercury.
3^3		27	. .	
3^2	9^1	9	. .	
3^1		3	. .	
3^0	9^0	1	1	Sun's semi-diameter.

This accordance is the more significant, because Saturn's secular aphelion is at the centre of the ring of secondary condensation, which extends from Sun's surface to Uranus's secular aphelion.

"Bode's Law,"[i] was based on successive differences of $2^0 \times 3$, $2^1 \times 3$, $2^2 \times 3$, etc. If we subtract 1 from each of the theoretical Bode numbers, and divide the remainders by 3, the quotients are 1, 2, 3, 5, 9, 17, etc., each of the quotients, except those for Venus and Neptune, being of the form $d_{n+1} = 2\,d_n - 1$; the dense-belt series being of the form $d_{n+1} = 3\,d_n - 1$.[ii]

In the infinite series, $\frac{1}{2} + 3^{-\infty} + 3^{-\infty+1} + \ldots 3^{-1} + 3^0 + 3^1 + 3^2 + \ldots$, successive sums, in the neighborhood of unity, give the following accordances:

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[i] This Journal, Sept., 1877, p. 162.

[ii] *Ibid.*, Nov., 1877, p. 352.

Sums.		Harmonic Divisors.	Quotients.	Observed.
$\frac{1}{2}$	=	$\frac{1}{2}$	27·38	27·00 = 3^3.
$+ 3^{-\infty}$		.	.	.
+ .		.	.	.
+ .		.	.	.
$+ 3^{-4}$		$\frac{14}{27}$	26·40	26·20 Extreme major-axis.
$+ 3^{-3}$		$\frac{5}{9}$	24·64	24·39 Mean major-axis.
$+ 3^{-2}$		$\frac{2}{3}$	20·53	20·68 Extreme secondary radius.
$+ 3^{-1}$		1	13·69	13·69 Nebular radius.
$+ 3^{0}$		2	6·85	6·85 Deimus.
$+ 3^{1}$		5	2·74	2·73 Phobus.
$+ 3^{2}$		14	·98	1·00 Semi-diameter of Mars.
$+ 3^{3}$		41	·33	·33 Oscillatory centre.
$+ 3^{4}$		122		120·56 Moon's major-axis.
$+ 3^{5}$		365		365·26 Terrestrial acceleration.
$+ 3^{6}$		1094		1096·20 Jupiter's semi-major-axis.

The "Extreme major-axis" is the major-axis of an ellipse, connecting the inner planets of the two outer two-planet belts at the secular aphelia of Uranus and Jupiter; the "Mean major-axis" is the sum of the mean distances of Uranus and Jupiter; the "Extreme secondary radius" is Uranus's aphelion radius, or the semi-diameter of the ring of secondary condensation; the "Nebular radius" not only represents the theoretical incipience of Mars's nebular condensation, but it also corresponds, almost precisely, with the sum of the secular perihelia of Jupiter (4·886) and Saturn (8·734), in units of Earth's semi-major-axis—the secular perihelion being the time of greatest orbital *vis viva;* "Moon's major-axis" is also Earth's "Nebular radius;" the "Terrestrial acceleration" represents the theoretical increase in the angular velocity of Earth's rotation, since its rupture from the central nucleus, or the ratio of its day to its year; "Jupiter's semi-major-axis" is measured in units of Sun's mean perihelion distance from the centre of gravity of Sun and Jupiter.

The sum of the infinite series, to and including 3^{-3}, is $\frac{5}{9}$, which represents the ratio of *vis viva* between undulatory velocity and the velocity of the particles of a medium constituted according to the Kinetic theory.[i] Alexander has shown the importance of that ratio in planeto-taxis,[ii] and I have shown that it represents "centres of

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[i] Maxwell and Preston, *Phil. Mag.*, June, 1877.

[ii] "Smithsonian Contributions," 280.

explosive oscillation," or the centre of secondary oscillation between the primary centre of oscillation and the centre of gravity, in a homogeneous line of particles ($\frac{2}{3} - \frac{2}{3}$ of $\frac{1}{6} = \frac{5}{9}$). Adding the next term of the series, we get $\frac{2}{3}$, which represents the centre of linear oscillation. Neptune's major-axis (60·06) is, within $\frac{1}{10}$ of 1 per cent. $(3^4 - 3^3 + 3^2 - 3^1 = 60)$ times Earth's mean radius vector.

These harmonies embrace orbital radii of the largest five planets of the solar system, of the inner planets, and of the asteroidal belt, together with nebular-, satellite-, and planetary-radii, for the outer and the middle planets in the theoretically primitive central belt, or the belt of greatest condensation. Can any interpretation be rightly put upon such a chain of harmonies, which does not recognize the fundamental laws of harmonic oscillation and harmonic design?

Neither of Mars's moons is of sufficient magnitude to cause any great perturbations. To this fact, perhaps, as much as to the proximity of the density-centre, we may attribute the regularity of the Mavortian system. In the solar system, as we have seen,[1] the preponderating mass of Jupiter sets up a new order of differences in the harmonic denominators; and we may find probable indications of similar influence in some of the satellite systems, and in the elementary spectra.

In the satellite system of Uranus, if we take the semi-major-axis of the outer satellite as the common numerator (22·75), we find the following harmony:

Satellites.	Distances.	Denominators.	Theoretical.
Oberon,	22·75	1·000	1·000
Titania,	17·01	1·337	$1·343 = 1 + 2\,a$
Umbriel,	10·37	2·194	$2·199 = 1 + 7\,a$
Ariel,	7·44	3·058	$3·055 = 1 + 12\,a$
Semi-diameter,	1·00	22·750	$22·750 = 1 + 127\,a$

In the Saturnian system there is a slight uncertainty in the satellite elements, except in the case of Titan, whose orbit was well determined by Bessel. It will be seen that Titan's great mass introduces a secondary harmony. The following harmonic denominators are based upon relative mean distances which would represent the orbital times, as furnished by Professor Hall:

[1] This JOURNAL, Sept., 1877, p. 167.

Satellites.	Times.	Denominators.	Theoretical.	
Japetus,	79·3292^d	1·000	1·000	
Hyperion,	21·3113	2·402	2·397 =	$1 + a$
Titan,	15·9454	2·914	2·920	$1 + b$
Rhea,	4·5175	6·756	6·760	$1 + 3b$
Dione,	2·7369	9·436	9·384	$1 + 6a$
Tethys,	1·8878	12·087	12·179	$1 + 8a$
Enceladus,	1·3702	14·966	14·974	$1 + 10a$
Mimas,	·9425	19·206	19·166	$1 + 13a$
Semi-diameter,		64·359	64·360	$1 + 33b$

It is well to notice that b (1·920) is very nearly the square of a (1·397).

In the column of times, Japetus, divided by Titan, is nearly 5; Hyperion, by Rhea, 5; Dione, by Enceladus, 2; Tethys, by Mimas, 2; Titan, by Rhea, $\frac{7}{2}$; Rhea, by Dione, $\frac{5}{3}$; Hyperion, by Titan, $\frac{4}{3}$; Hyperion, by Dione, 8; Hyperion, by Mimas, $\frac{45}{2}$; Titan, by Mimas, 17.

The satellite system of Jupiter, our Sun's "companion star," exhibits harmonies of distance, time and mass. The mean distance of the outer satellite, Callisto, is 3^3 semi-diameters of its primary (26·9984). Using this as a common numerator, we find that the other satellites are phyllotactically, as well as harmonically, arranged:

Satellites.	Distances.	Denominators.	Theoretical.	
Callisto,	26·9984	1·000		
Ganymede,	15·3502	1·759	1·731 =	$5a$.
Europa,	9·6235	2·807	2·769	$8a$.
Io,	6·0485	4·464	4·500	$13a$.
Semi-diameter,	1·0000	26·998	26·998	$78a$.

The harmonies of time and mass are as follows:

Satellites.	Times.	Theoretical.		Mass.	Theoretical.	
Callisto,	16·689^d	16·684 =	$28t$	4266	4403 =	$\frac{1}{2}m$.
Ganymede,	7·155	7·150	$12t$	8850	8806	$1m$.
Europa,	3·551	3·575	$6t$	2324	2202	$\frac{1}{4}m$.
Io,	1·769	1·788	$3t$	1733	1761	$\frac{1}{5}m$.

A DECIMAL GAUGE FOR SHEET METAL AND WIRE.

By Robt. Briggs, C. E.

Various standards of measurement, designated as gauges, which are a series of notches of several widths made in the edge of a metal plate, the widths of the notches bearing some relative proportion of gradation from small to large, have become established by time and customary local or trade usage of English metal workers or dealers. These gauges are purely arbitrary, both in dimension and relative proportion of the notches. In regard to dimension, they do not refer to any other unit of measurement—each notch is an original dimension of itself—nor do they have any definite relation to weights of sheets of given superficies, or of wire of given lengths; so that to the unpracticed mechanic of the schools or books, they seem to be "thoroughly senseless," to quote the words of a very intelligent technical author and compiler. As for relative proportion of the gradation, it can be said, after close examination, that there *is* an evident attempt to have the differences of thickness which follow each other, in some manner proportionate—they are the *guess* of the workmen at a geometric proportion of dimension.

The gauges were of local origin at first, and each locality where sheet metal or wire was made or worked, and even each kind of sheet or wire, as iron, steel, copper, brass, silver, etc., had its own trade gauge. This general development of the system of gauges may be fairly claimed to support the "sensibility," if not desirability or necessity, for their existence. Of late years the gauge known as the Birmingham gauge has been perpetuated with much care, and with general exactness of repetition, by the firm of Messrs. "Stubs," of Warrington, England, and has gradually come into use in supersession of most of the other gauges. An especial gauge for brass sheets or wire has held its place in England against the encroachment of the "Stubs" Birmingham gauge, to some extent at least; while in the United States a so-called American gauge has nearly supplanted the brass gauge, and has met with some use in the measurement of iron sheets or wire.

The gauges, all of them, refer to small dimensions relative to the inch, so small that the dimensions cannot be measured by any rule,

even one with sixteenth divisions of the inch upon it. With finer divisions, say hundredths of an inch, which have been attainable within the past twenty years, a comparison of a callipered dimension has been possible to the limit of exactness which the $\frac{1}{100}$ of an inch will give. But this degree of accuracy is much below the wants of the workman, who demands that the measurement of thickness shall control the weight of the plate per square foot, or of wire per lineal foot, and even the hundredth of an inch becomes of large value in the differences of the lighter gauges.

There is a real necessity for the *gauge* as a means of measurement, and, more than this, there is a *necessity that the division should not follow the ordinary notation of figures.* An examination of the various gauges of old—the Birmingham iron (which is the present "Birmingham"), the Birmingham brass, the Lancashire, the rod gauges—shows that there is a rough approximation to the scale of proportionate dimension throughout them all. The fact is made evident that the workman desired that the next number to any given two numbers or pair, above or below, should be greater or less in thickness in proportion to the increase or reduction which had been established in making the differences of the pair assumed. In other words, the workman did not require a uniform increase as 1, 2, 3, 4, 5; but one as $1, 1 + \frac{1}{4}, 1\frac{1}{4} + \frac{1}{4}$ of $1\frac{1}{4}$, etc.; he *required* not an arithmetic, but a geometric, proportion. Thus, for the purposes of trade, let it be supposed that plates $\frac{10}{100}$ of an inch are wanted for some one use, it is evident that $\frac{9}{100}$ might be a suitable dimension to meet a similar demand for a less requirement of strength or thickness, and that, in practice, intermediate dimensions might not be demanded as merchantable; while descending in thickness by units, until $\frac{2}{100}$ are reached, it is apparent that several merchantable thicknesses ought to exist between this dimension and $\frac{1}{100}$, or half its thickness; and, pursuing the argument *ad absurdum*, it cannot be argued that no metal ought to be kept as an article of sale less than $\frac{1}{100}$ of an inch in thickness, because the numbers run out in units of hundredths of an inch at this point. In mathematical language, the gauges are not expressed in arithmetical notation, but in an exponential one, and the numbers of the steps represent $a\,m^N$, where a is a co-efficient of length or of weight, m is the common ratio or modulus of the system, and N is the characteristic or exponent assumed in any instance.

This law of the formation of a scale of gauges was fully recognized some twenty years since, by Messrs. Brown and Sharpe, of Providence, R. I., who then proposed to correct the discrepant proportions of the Birmingham gauge, by establishing a regular proportion of the 39 successive steps between the 0000 and 36 of that gauge. In this case the value of 0·46 inch has been taken as that for 0000, or the largest dimension of the scale, then by successive uniform decrements, each number following being derived by multiplying the former one by 0·890522 (or deducting 10·9478 per cent.); the final value for number 36 is reached at 0·005 inch, which figure corresponds to number 35 of the Birmingham gauge. This gauge was named the "American" gauge, and has been largely made by the proposers.

But this gauge, with all its correctness of system of proportionate parts, has met with little favor from practical men, and none at all beyond the limits of the trade influence of its makers, whose reputation for accuracy of workmanship in instruments of measurement in other regards, as well as in furnishing these gauges of constant and unimpeachable exactness, has commended a favorable introduction to all American mechanics. The old gauge, to those who use it most, is a scale of dimensions which they think in, as positively as an Englishman thinks in English; its differences are near enough proportionate in the limits of five or six steps to serve to think about, in giving dimensions to a vessel of any kind, and even the irregularities are fixed in the mind so that the error in proportion is measurably removed. A new scale of figures, which in some places differs one or two numbers from the old one, becomes to these men a source of confusion of ideas. To such workmen or users no substitute gauge would commend itself which did not present more advantage than the sentimental one of exact sequence in proportion that had been attained by the adoption of a rate of proportion altogether beyond his ability to comprehend.

The requirements of a gauge, however, have changed in the last fifty years. Uniformity, as one, has been satisfied in degree by the conflict of local gauges, in which it may be presumed that the "fittest," the Birmingham, has survived—although it may be possible that the Birmingham gauge owes its victory to the skill of its advocates and makers, and not to especial fitness. Accuracy has been secured by careful measurement of the gauge spaces, and comparison to the

standard linear units of the land. Elaborate tables give the value in inches and decimals of the several dimensions, and also give the exact computed weights of superficies, sheet metal, or lengths of wire of the several metals of commerce.

The requirement of a uniform proportionate gradation of the steps of the gauge may be fully admitted, but whatever proportion is adopted, it should be a simple one. The great use of the gauge to-day is for the purpose of estimate—for calculating the value of given superficies or lengths in weight of material, or *vice versa*, if it can be made more convenient for this end by a new notation or new division of parts, then a change can be advocated and certainly in the end effected.

There are some results from any gauge which must be tabular. The requirement of proportionate sequences leaves but one set of numbers in our arithmetic notation, which will conform; this set of numbers is 1, 10, 100, 1000, etc., where each number is ten times the one before it. This difference is out of the question, and any other proportionate difference leads to interminable figures. It must be accepted, therefore, that with any modulus or difference of ratio between any two steps of the gauge, there can be but *two* points in the scale where an even number can occur, or where any assumption of an arbitrary value will be possible, and if the modulus is established with any rational or aliquot number, there can be but *one* single value in the whole scale which can be expressed in even numbers, or arbitrarily assumed for any value. The values of a series of relatively proportionate sizes must therefore be expressed by decimals, and be derived for practical convenience from a table, and not deduced by special calculation each time. Again, the complicated relation of our English units of weights and measures, together with the various specific gravities of the metals to be gauged, give tabular values for weights which derive exactness only from long extension of decimals, and are utterly devoid of simple expression.

The proposed Decimal Gauge is based upon the successive reduction of an assumed unit of dimension by one-tenth, or, what is the same thing, of successive increase of its divisions by one-ninth.

The establishment of the unit which should be the base of this scale, has been duly considered. This unit has the characteristic number of zero (0), and observation shows, that supposing it is advisable to have the new gauge conform in the main with the Birmingham

gauge, then one centimetre = 0·3937079 inches, very satisfactorily fulfils this demand. This value differs one number from the Birmingham one, but this difference gradually disappears in the irregular proportion of the Birmingham gauge, until at No. 8 the two systems nearly coincide. The coincidence continues for 6 numbers to No. 14, after which the new gauge becomes thicker than the Birmingham, with smaller differences, so that three more numbers are needed in the decimal gauge to cover the same range of thickness.

At this point it is only necessary to refer to the scale and to the tables of comparison. So far as relative difference between pairs of numbers is concerned, inspection of the column of Birmingham gauges in Table I, will show that between Nos. 000 and 4 – 6 spaces, the decrease for each size is $\frac{1}{10}$, nearly, and the same between Nos. 8 and 12 – 4 spaces, and also the same between Nos. 20 and 30 – 10 spaces; so that 20 spaces out of the 39 follow, with close approximation to exactness, the rule of uniform reduction of one-tenth. The ideal perfect gauge of the workman may be fairly accepted as having this ratio of differences! The adoption of this ideal involves the regulating of values which the true decimal gauge effects, when the substitution of new values in the scale at the places of discrepancy necessitates three or four more numbers.

The plate accompanying this paper, represents the Decimal, Birmingham and American gauges graphically, showing the irregularities of the Birmingham gauge as derived from figures given in the text books (the authority of which figures is "Holtzapfel's Mechanical Manipulation," 1846), but some allowance must be made for inaccuracy of measurement of the smaller gauges, where the decimal values are carried out to only two, and below No. 32 to only one figure. The enlarged diagram on the plate, gives in dotted line a more correct view of the Birmingham gauge from No. 30 to 36.

Returning to the question of value to be assumed for the unit of thickness, there was another metric value which presented some points of merit. The solid volume of a sheet measuring 1 square metre, and having a millimetre of thickness, is equivalent to a cubic decimetre, again represents the litre or measure of capacity (= 1·05656 American quarts = 0·88025 English quart) and the kilogramme of water (= 2·204737 avoirdupois pounds). If the millimetre were taken for the unit, the "0" of the gauge would be about No. 20 of the Birmingham gauge. From this unit the numbers would range upwards and

downwards; in the upward direction "plus" 23 would be a little less than the Birmingham 0000 in thickness. With this unit of thickness as the starting point, the weight of sheets of iron, steel, copper, brass, or other metal corresponding to it, per metre square of surface, represents the specific gravity of the material. That is, as a litre of water weighs one kilogramme, the metre square of iron of one millimetre in thickness, *having the same cubic volume*, weighs 7·77 kilogrammes, and with other metals the same relationship to the comparative weight of water for sheets one metre square by one millimetre in thickness, exists. The objection to this value is the disturbance of the relationship of numbers to thicknesses of sheets, or diameter of wires, which is now so positively fixed in the minds of the "trade." It makes no real difference whether the scale of figures runs up or down. No unit can be taken which will be so large or so small that it can be adopted as a starting point from which to proceed upwards or downwards only. Certainly the thickness of 0·039 of an inch is not so small that negative or descending numbers will not be a necessity, while the number 0·39 of an inch is in fact so large, that, as a scale of numbers, the sizes above zero are not to be classed as merchantable. This last qualification being one of the main conditions of sheets and wire, which are measured by a gauge. And if the unit be taken at a centimetre in place of a millimetre, the relation of weights of a metre square of sheets to specific gravities is yet preserved to all intents and purposes, being only increased by multiplying by ten; the metre square sheet of iron, which has the thickness of a centimetre, weighing 77·7 kilos., while its specific gravity is 7·77.

On the whole, the adoption of the centimetre as the unit of thickness, which shall represent zero in the exponential scale of numbers, seems to meet at once the demands of conformity with natural constants, and also with the habitual *thought* of the metal and wire workman.

A decimal progressive scale could be made in either of two ways—it can either increase or decrease by a decimal rate. Thus, if one-tenth is added each time to a series of numbers, the retrograde steps will be the deduction of one-eleventh, and on the other hand, if one-tenth be deducted each time, to form a similar series, the increase of each number will be one-ninth added to that below it. Either of these ways is equally advantageous in use for computing, but the

one-tenth of addition will give nearly 24 steps in passing from one to ten, while the one-tenth of deduction gives nearly 22 steps in passing from ten to one. This small difference of number of steps would have little effect in the decision as to which system to follow, except that the Birmingham gauge has from 18 to 20 steps in the passing from any of its values to those ten times as great. [The "American" gauge gives very nearly 20 steps in this change of values, but as it avoids one-ninth deduction (or one-eighth addition) by the least of difference, so also it avoids the equal stepping off of the space of two-fold increase with 20 steps by a small fraction.] As it has been shown before, that the Birmingham gauge has a large portion of its spaces at one-tenth deduction, and as 22 steps in ten-fold increase or decrease most nearly correspond to the known gauge of commerce, it would appear that $\frac{9}{10}$ is a more proper basis for the new gauge than $\frac{11}{10}$, and the plate and tables follow $a\left(\frac{9}{10}\right)^N$ as the most suitable base.

It remains to be shown what advantages are to be derived from the adoption of this gauge. It will give a scale of proportionate dimensions for all the practical sizes of thickness of sheet metal and diameter of wire; which scale can be extended upwards or downwards to cover any possible future demand. The American gauge already does this, so far as uniform proportion is concerned, equally well. But the decimal gauge gives a numerical proportion which is easily remembered and readily used in computation. In sheet metal especially, it is the constant requirement upon the workman to estimate for weights. Having calculated with much care the weight of a vessel or tank, a boiler or cauldron, for some assumed thickness, it would be a great boon to him to be able at once to increase or reduce the weight of the same to suit conditions, without resorting to a new set of figures. If such a thing is to weigh 10 per cent. less than it "comes out," then a gauge off from the thickness of the plates will surely accomplish the reduction. If a purchaser desires an article of sheet iron to be of a certain gauge, when its weight of another gauge is known, the transformation becomes easy. For the transformation of weights of wire of given lengths, but varying gauges, the same simple reduction of tenth, or increase of ninth, parts follows; only there are two *successive* reductions or increases to be made for each number in place of one, as the areas of sections of wire vary as the squares and not as the diameters, and we take $\left(\frac{9}{10}\right)^2$, as the difference of each step of weight of wire.

It must not be supposed that any system will divest the computer in metal work from the use of tables and long lines of decimals. The relation of weights of various metals to their volume is not to be expressed in units. A cubic decimetre of water weighs 1 kilogramme, but a cubic decimetre of iron weighs, sometimes, 7·7694 kilogrammes. No system can simplify this relationship. An inch thick of iron 1 foot square weighs 40·4167 lbs. Were this simplified by making a special pound weight to 40 lbs., even then a plate of iron, $\frac{13}{64}$ in thickness, has not a very convenient arrangement of decimals for its weight per square foot. Expressing thicknesses in any order of figures that may be taken, will not eliminate the long rows of tabular values which must follow the incompatible data needed in practice. But if the proportions of thickness and diameter of commercial and usual sheets and wire are made uniform in the first place, and then have simply related values, such values can be used in computation of the tables, and the relative proportions can be applied to results obtained from the tables.

One more advantage may follow the introduction of a decimal gauge as here described. There exists an absolute necessity for such a gauge, with its exponential in place of arithmetic notation. That such a gauge can be made to become uniform in all nations, the adjustment of the unit to the metric system may offer some inducement to other countries. The Birmingham unit of 0·34 of an inch is purely arbitrary, and out of agreement with any unit of measurement, English or foreign, while the proposed unit of a centimetre = 0·3937 of an inch, gives a standard which is admitted in all lands. If this decimal gauge can be made a universal measure for sheet metal all over the world, it will then have accomplished an end second only in importance to its practical application to the wants of the workmen of England and America.

NOTE.—The foregoing paper appears at this time as the result of an inquiry by Prof. Hilgard, of the U. S. Coast Survey, from the writer about two months since: "What do you know about wire gauges?" The answer then given was that I had examined the subject quite fully many years, 20 or more, since, and had reached conclusions satisfactory to myself, at least, among which were: that they were a necessity to the sheet metal or wire maker, dealer or worker; that the thicknesses indicated by the numbers should vary proportionately by a common ratio, and not arithmetically by constant difference; that the value of the common ratio should be a simple one,

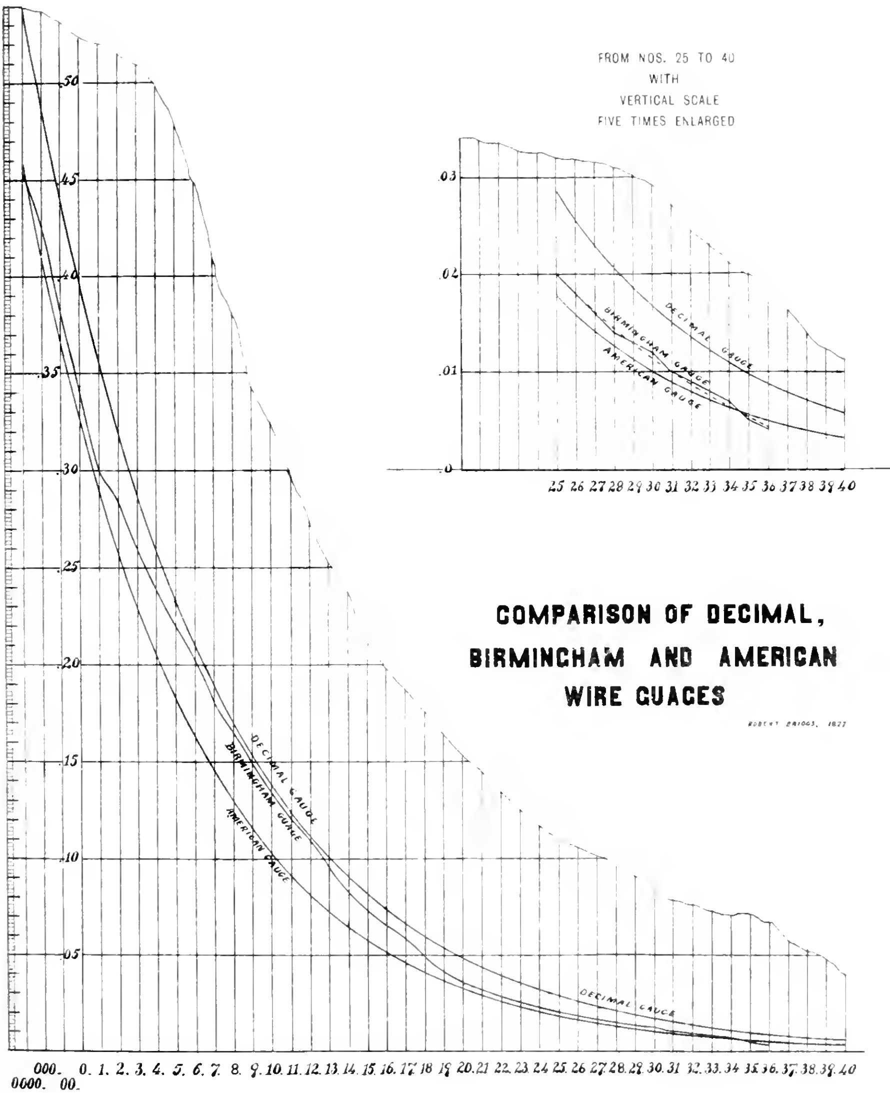

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Table I.

Comparison of Decimal, Birmingham & American Wire Gauges.

Dimensions in English Inches, with Corresponding Dimensions for Decimal Gauge in Centimetres.

No. of Gauge.	Decimal Gauge. Centimetres.	Decimal Gauge. Inches.	Birmingham Gauge. Inches.	American Gauge. Inches.
0000 = —3	1·3717	0·5401	0·454	0·46
000 = —2	1·2346	0·4861	0·425	0·4096
00 = —1	1·1111	0·4375	0·38	0·3649
0 = 0	1·	0·3937	0·34	0·3249
1	0·9.	0·3543	0·3	0·2893
2	0·81	0·3189	0·284	0·2576
3	0·729	0·2870	0·259	0·2942
4	0·6561	0·2583	0·238	0·2043
5	0·5905	0·2324	0·22	0·1819
6	0·5314	0·2092	0·203	0·1620
7	0·4883	0·1883	0·18	0·1443
8	0.4305	0·1695	0·165	0·1285
9	0·3874	0·1525	0·148	0·1144
10	0·3487	0·1373	0·134	0·1019
11	0·3138	0·1236	0·12	0·09074
12	0·2824	0·1112	0·109	0·08081
13	0·2542	0·10008	0·095	0·07196
14	0·2288	0·09007	0·083	0·06408
15	0·2059	0·08106	0·072	0·05707
16	0·1853	0·07296	0·065	0·05082
17	0·1668	0·06566	0·058	0·04526
18	0·1501	0·05909	0·049	0·04030
19	0·1351	0·05318	0·042	0·03589
20	0·1216	0·04787	0·035	0·03196
21	0·1094	0·04307	0·032	0·02846
22	0·09848	0·03877	0·028	0·02535
23	0·08863	0·03489	0·025	0·02257
24	0·07977	0·03140	0·02	0·02010
25	0·07179	0 02864	0·018	0·01790
26	0·06461	0·02544	0·016	0·01594
27	0·05815	0·02289	0·014	0·01419
28	0·05233	0·02060	0·013	0·01264
29	0·04710	0·01854	0·012	0·01126
30	0·04239	0·01669	0·010	0·01003
31	0·03815	0·01502	0·009	0·008928
32	0·03434	0·01351	0·008	0·007950
33	0·03090	0·01217	0·007	0·007080
34	0·02781	0·01095	0·005	0·006304
35	0·02503	0·009856	0·004	0·005614
36	0·02253	0·008870		0·005000
37	0·02028	0·007983		0·004453
38	0·01825	0·007185		0·003965
39	0·01642	0·006466		0·003531
40	0·01478	0·005819		0·003144

Table II.

Weight of One Square Foot of Sheet Metal, or One Foot in Length of Wire, of Thicknesses or Diameters given by the Decimal Gauge; English Units.

No. of Gauge.	Thickness or Diameter.	One square foot of sheet metal. Iron, pounds.	Steel, pounds.	Copper, pounds.	Brass, pounds.	One foot in length of wire. Iron, pounds.	Steel, pounds.	Copper pounds.	Brass, pounds.
—3	0·5401	21·8277	22·0460	24 4650	23·1148	0·76359	0·77926	0·88290	0·85052
—2	0·4861	19·6449	19·8413	22·0185	20·8033	0·61851	0·63120	0·71515	0·68892
—1	0·4375	17·6801	17·8572	19·8167	18·7230	0·50099	0·51127	0·57927	0·55803
0	0·3937	15·9124	16·0715	17·8350	16·8507	0·40580	0·41413	0·46921	0·44300
1	0·3543	14·3211	14·4643	16·0515	15·1656	0·32870	0·33545	0·38006	0·35883
2	0·3189	12·8890	13·0178	14·4463	13·6490	0·26624	0·27171	0·30785	0·29066
3	0·2870	11·6001	11·7161	13·0017	12·2841	0·21566	0·22009	0·24936	0·23543
4	0·2583	10·4401	10·5445	11·7015	11·0557	0·17468	0·17827	0·20198	0·19070
5	0·2324	9·3961	9·4901	10·5313	9·9501	0·14150	0·14440	0·16360	0·15446
6	0·2092	8·4565	8·5411	9·4782	8·9551	0·11461	0·11696	0·13252	0·12512
7	0·1883	7·6168	7·6869	8·5304	8·0596	0·09283	0·09474	0·10734	0·10134
8	0·1695	6·8498	6·9182	7·6774	7·2536	0·07520	0·07674	0·08695	0·08209
9	0·1525	6·1648	6·2264	6·9096	6·5283	0·06091	0·06216	0·07043	0·06649
10	0·1373	5·5483	5·6037	6·2187	5·8755	0·04934	0·05035	0·05705	0·05386
11	0·1236	4·9935	5·0434	5·5967	5·2879	0·03996	0·04078	0·04621	0·04363
12	0·1112	4·4941	4·5400	5·0371	4·7591	0·03237	0·03303	0·03743	0·03534
13	0·10008	4·0447	4·0851	4·5334	4·2832	0·02622	0·02676	0·03032	0·02862
14	0·09007	3·6402	3·6760	4·0801	3·8549	0·02124	0·02167	0·02456	0·02318
15	0·08106	3·2762	3·3090	3·6721	3·4694	0·01720	0·01756	0·01989	0·01878
16	0·07296	2·9486	2·9781	3·3048	3·1225	0·01393	0·01422	0·01611	0·01521
17	0·06566	2·6537	2·6822	2·9744	2·8102	0·01129	0·01152	0·01305	0·01232
18	0·05909	2·3884	2·4123	2·6769	2·5292	0·009142	0·009330	0·01057	0·609980
19	0·05318	2·1495	2·1710	2·4092	2·2763	0·007405	0·007557	0·008562	0·008084
20	0·04787	1·9346	1·9539	2·1683	2·0487	0·005998	0·006121	0·006935	0·006548
21	0·04307	1·7411	1·7585	1·9515	1·8438	0·004858	0·004958	0·005618	0·005304
22	0·03877	1·5670	1·5827	1·7563	1·6591	0 003935	0·004016	0·004550	0·004296
23	0·03489	1·4103	1·4244	1·5807	1·4935	0·003188	0·003253	0·003686	0 003480
24	0·03140	1·2693	1·2820	1·4226	1·3441	0·002582	0·002635	0·002985	0·002819
25	0·02864	1·1423	1·1537	1·2804	1·2097	0·002091	0·002134	0·002418	0·002283
26	0·02544	1·0281	1·0384	1·1523	1·0887	0·001694	0·001729	0·001959	0·001849
27	0·02289	0·9253	0·9346	1·0371	0·9799	0·001372	0·001400	0·001587	0·001498
28	0·02060	0·8328	0·8411	0·9334	0·8819	0·001111	0·001134	0·001285	0·001213
29	0·01854	0·7495	0·7570	0·8401	0·7937	0·0009003	0·0009188	0·001041	0·0009828
30	0·01669	0·6745	0·6812	0·7560	0·7143	0·0007292	0·0007442	0·0008432	0·0007961
31	0·01502	0·6071	0·6132	0·6804	0·6429	0·0005907	0·0006028	0·0006830	0·0006448
32	0·01351	0·5464	0 5519	0·6124	0·5786	0·0004785	0·0004883	0·0005532	0·0005223
33	0·01217	0·4917	0·4966	0·5512	0·5207	0·0003876	0·0003955	0·0004481	0·0004231
34	0·01095	0·4426	0·4470	0·4960	0·4687	0·0003139	0·0003204	0·0003630	0·0003427
35	0·009856	0·3983	0·4023	0 4464	0·4218	0·0002543	0·0002595	0·0002940	0·0002776
36	0·008870	0·3585	0·3621	0·4018	0·3796	0·0002060	0·0002102	0·0002381	0·0002248
37	0·007983	0·3226	0·3258	0·3616	0 3417	0·0001668	0·0001702	0·0001929	0·0001821
38	0·007185	0.2904	0·2933	0·3255	0·3075	0·0001351	0·0001379	0·0001562	0·0001475
39	0·006466	0·2613	0·2639	0·2929	0·2767	0·0001095	0·0001117	0·0001266	0·0001195
40	0·005819	0·2352	0·2376	0·2636	0·2491	0·00008866	0·00009048	0·0001025	0·00009678
Specific Gravity.		7·769	7·847	8·708	8·228	7·6893	7·847	8·891	8·394
Weight per cu. ft.[1]		485	489·85	513·6	513·6	480	489·85	555	524
Weight per cu. in.		0·28067	0·28348	0·3146	0·2972	0·2807	0·2836	0·3212	0·3033
Weight 1 ft. long, 1 in. round.		2·6153	2·6717	2·95	2·8012	2·6180	2·6717	3·0283	2·8580

[1] These figures for weight per cubic foot were adopted from Trautwine.

Table III.

Weight of One Square Metre of Sheet Metal, or One Metre in Length of Wire, of Thicknesses or Diameters given by the Decimal Gauge; Metric Units.

No. of Gauge.	Thickness or Diameter. Centimetres.	One square metre of sheet metal. Iron, kilos.	Steel, kilos.	Copper, kilos.	Brass, kilos.	One metre in length of round wire. Iron, kilos.	Steel, kilos.	Copper, kilos.	Brass, kilos.
—3	1·3717	106·576	107·643	119·453	112·860	1·13637	1·04373	1·31391	1·24054
—2	1·2346	95·9185	96·8777	107·508	101·574	0·92046	0·93935	1 06427	1·00484
—1	1·1111	86·3267	87·1900	96·7568	91·4170	0·74557	0 76088	0·86206	0·81392
0	1·	77·6940	78·4707	87·0811	82·2753	0·60391	0·61631	0·69827	0·65928
1	0·9	69·9246	70·6238	78·3730	74·0478	0·48917	0·49921	0·56560	0·53401
2	0·81	62·9321	63·5614	70·5357	66·6430	0·39623	0·40436	0·45813	0·43255
3	0·729	56·6389	57·2053	63·4821	59·9787	0·32094	0·32753	0·37109	0·35037
4	0·6561	50·9750	51·4847	57·1339	53·9808	0·25997	0·26530	0·30058	0·28380
5	0·5905	45·8775	46·3463	51·4205	48·5827	0·21057	0·21489	0·24347	0·22988
6	0·5314	41·2898	41·7027	46·2784	43·7244	0·17056	0·17406	0 19721	0·18620
7	0·4883	37·1618	37·5334	41·6506	39·3520	0·13816	0·14099	0·15974	0·15082
8	0 4305	33·4447	34·7891	37·4855	35·4168	0·11191	0·11420	0·12939	0·12216
9	0·3874	30·1002	30·4012	33·7370	31·8751	0·090644	0·092504	0·10481	0·098953
10	0·3487	27·0901	27·3610	30·3633	28·6876	0·073422	0·074929	0·084894	0·080152
11	0·3138	24·3810	24·6248	27·3270	25·8188	0·059472	0·060692	0·068764	0·064923
12	0·2824	21·9429	22·1623	24·5945	23·2369	0·048172	0·049161	0·055699	0·052588
13	0·2542	19·7486	19·9461	22·1349	20·9132	0·039019	0·039820	0·045116	0·042596
14	0·2288	17·7737	17·9514	19·9214	18·8219	0·031606	0·032254	0·036544	0·034503
15	0·2059	15·9963	16·1563	17·9293	16·9397	0·025601	0·026126	0·029601	0·027947
16	0·1853	14·3967	14·5407	16·1364	15·2457	0·020736	0·021162	0·023977	0·022637
17	0·1668	12·9570	13·0866	14·5228	13·7211	0·016797	0·017141	0·019421	0·018336
18	0.1560	11·6613	11·1779	13·0705	12·3490	0·013605	0·013885	0·015731	0·014852
19	0·1351	10·4952	10·6002	11·7634	11·1141	0·011020	0·011246	0·012742	0·012031
20	0·1216	9·4457	9·5402	10·5871	10·0026	0·008926	0·009110	0·010321	0·009745
21	0·1094	8·5011	8·5861	9·5284	9·0022	0·007230	0·007374	0·008360	0·007893
22	0·09848	7·6510	7·7277	8·5756	8·1020	0·005857	0·005977	0·006772	0·006393
23	0·08863	6·8859	6·7548	7·7180	7·2918	0·004744	0·005379	0·005485	0·005179
24	0·07977	6·1973	6·2593	6·9462	6·5626	0·003843	0·004841	0·004443	0·004195
25	0·07179	5·5776	5·6336	6·2516	5·9064	0·003112	0·003176	0·003599	0·003398
26	0·06461	5·0199	5·0700	5·6264	5·3157	0·002521	0·002573	0·002915	0·002752
27	0·05815	4·5179	4·5631	5·0638	4·7842	0·002012	0·002084	0·002361	0 002229
28	0·05233	4·0661	4·1068	4·5574	4·3058	0·001654	0·001688	0·001912	0·001806
29	0·04710	3·6595	3·6961	4·1017	3·8752	0·001340	0·001367	0·001549	0·001463
30	0·04239	3·2936	3·3265	3·6915	3·4877	0·001085	0·0011075	0·001255	0·001185
31	0·03815	2·9612	2·9938	3·3223	3·1389	0·0008790	0·0008971	0·0010164	0·0009596
32	0·03434	2·6678	2·6945	2·9901	2·8251	0 0007120	0·0007266	0·0008233	0·0007773
33	0·03090	2·4010	2·4250	2·6911	2·5125	0·0005767	0·0005886	0·0006669	0·0006296
34	0·02781	2·1609	2·1825	2·4220	2·2883	0·0004204	0·0004767	0·0005402	0 0005100
35	0·02503	1·9418	1·9642	2·1798	2·0595	0·0003784	0·0003862	0·0004375	0·0004131
36	0·02253	1·7504	1·7679	1·9618	1·8535	0·0003065	0·0003128	0·0003544	0·0003346
37	0·02028	1·5753	1·5911	1·7656	1·6682	0·0002483	0·0002534	0·0002871	0·0002710
38	0·01825	1·4178	1·4320	1·5891	1·5013	0·0002011	0·0002052	0·0002325	0·0002195
39	0·01642	1·2760	1·2888	1·4302	1·3512	0·0001629	0·0001662	0·0001883	0·0001778
40	0·01478	1·1484	1·1599	1·2871	1·2161	0·0001319	0·0001346	0·0001526	0·0001440
Specific Gravity.		7·769	7·847	8·708	8·228[1]	7·6893	7·847	8·891	8·394[1]

[1] Value of specific gravity of brass sheets or wire dependent on the composition of brass.

etc., etc. After setting forth the scheme, and preparing an illustration of it graphically, as shown on the plate, its publication, as a matter of public interest, was advised by Prof. Hilgard. While going to press, I have been favored by the Professor with a copy of a communication addressed to him on October 26th, from the Department of Standards, Board of Trade, England, asking if there is any official gauge or standard measure in the United States for wire and sheet metals, and whether more than one gauge is used by manufacturers in America; and saying that in the German Empire there is some agitation for the establishment of a better gauge than the Birmingham or Dilhingen gauges now in use, and adverting to the *unsatisfactory* Birmingham gauge now in use in England. From all this it would appear that the present time is auspicious for the consideration of the subject of the paper in this and other countries.

A NEW SINE PENDULUM.

By Thomas William Tobin, Professor of Physics and Chemistry, Central University, Richmond, Kentucky.

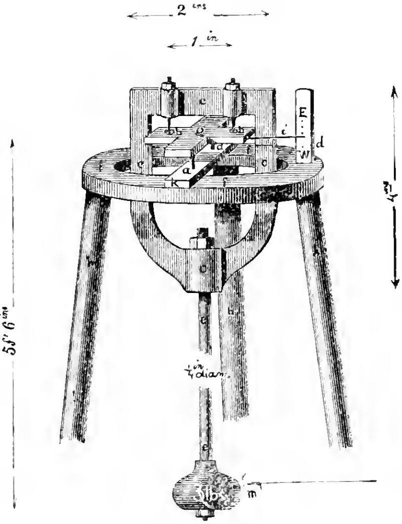
Having occasion to illustrate the properties of motion in my department of instruction, it occurred to me, as no doubt it has occurred to others, that the pendulum afforded many practical advantages usually overlooked in general illustrations. This, coupled with the fact that one of my brother professors, L. G. Barbour, was about to introduce the celebrated Foucault experiment as a lecture illustration, suggested to my mind the following instrument. I have worked at it with a degree of devotion which can only be repaid by the gratification afforded in the revelation of natural laws, and, I think, brought an instrument to a state of completion fitted for the use of those who, like myself, are engaged in scientific education. To such I present freely the results of these labors, in the hope that they may be the means of affording as much pleasure as I experienced in their pursuit:

Description of the Instrument.

The following description and drawing is intended to record the apparatus used in actual experiments, and which, having given satis-

factory results, I prefer to adopt rather than embody any improvements or additions which I would introduce in constructing another instrument. Such improvements or additions I will, however, record, leaving their incorporation discretionary on the part of the future manufacturer.

The pendulum is constructed of steel-rod, $\frac{1}{4}$ in. in diameter, and measuring, from the points of support to the extreme lower end, 5 ft. 6 ins.; it is tightly screwed together, so that the parts are compact; indeed, the whole instrument, when set up, must be in similar condition—firm and rigid in all its parts. There are two steel points, hardened and polished, at *b* and *b*, with adjustable check screws. When the pendulum is suspended from these points in perfect equilibrium, they must be in a truly horizontal plane; this condition is indispensable in obtaining accurate results. The pendulum is supported upon, but in no way attached to, a cross-piece, *g*, made of hardened steel or brass, having four agate cups equally distant from its centre. These cups are accurately ground and polished and set, two into the upper surface of two opposite arms, and two in the under surface of the other arms, in such a manner that the crowns or extremities of the sinkings of all four cups are in the same plane. Below this is an oblong piece of steel, *k*, having two adjustable polished steel points, *a*, *a*, of like construction to those in the pendulum-head, and corresponding to the lower surface agate cups, in *g*, to receive them. Thus fitted together, the whole is supported upon a strong tripod with a circular opening, as shown. Attached to the cross-piece, *g*, at the extreme corner of the right arm, is an index, *i*. A scale, *d*, is mounted upon the tripod: this scale may be divided in ·01 of an inch, or other convenient units.



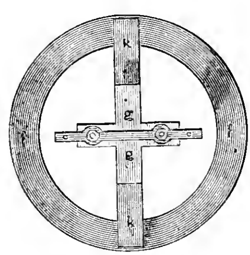
Front View.

To adjust the pendulum, it should be mounted as shown in the drawing, all the parts being leveled, and whatever plane the pen-

dulum is started in, that plane must be preserved by it without variation. Should the vibration become elliptical, the cause may be found in imperfect mounting. Before actual use it may be started in a circular direction, and if that quality of rotation is preserved, the indication points to perfect equilibrium of the parts. Should it, however, degenerate into a lineal motion, then the points parallel with the plane of oscillation will probably be found imperfect. Any quality of vibratory motion ought to be preserved for at least twelve hours.

Having the parts in perfect order, the instrument may be started. It does not matter in which position the plane of vibration is situated, but, for reference, the following is suggested. The observer standing in front of the instrument, the opposite direction may be called north; that towards him, south; the right hand, east; and left, west. A hook should be attached firmly to an adjoining wall, about five feet or more distant, due north, and a thin silk cord passing through the hook and attached to the pendulum at m, the other end being held in the hand of the observer. This cord may be detached when the ball is in motion, without disturbing the quality of the vibration.

N

W  E

S

Plan.

Now upon pulling the cord gently about 2 ins., and waiting until all incidental vibration has ceased, it may be loosed, and the index marked. If the instrument is set exactly in the plane of vibration, the index will remain absolutely stationary; but this is seldom the case. It will probably move, and the movement must be noted. If the index moves east on the scale, while the pendulum is north, then the plane of vibration is east of north. The entire pendulum may be moved, by means of the plate, k, upon the tripod in a northeast direction. I would recommend a tangent screw for this purpose, but have not as yet used one, and, therefore, it is not shown in the drawing. If the index points west, while the pendulum is north, the plate, k, will of course have to be moved northwest, to bring it to a normal condition. These movements are of a very delicate nature, and require skill and patience in adjustment.

Having arranged the instrument so that upon starting the pendulum gently, the index remains perfectly still, the silk cord may then be detached by carefully lifting it off the hook, m, and the time noted. Vibrations of the index will become apparent in from one to two minutes; their value for the hourly motion of the earth, is estimated by the formula given as under.

Instead of the index a small mirror may be attached to the cross-piece, g, and, by means of a lamp, a spot of light reflected to a distance of several feet or more, and thus giving the indications greater amplitude. I would prefer a heavier pendulum-ball than that used hitherto, and a longer rod, say 6 ft., instead of 5 ft. 6 ins. The points of support might also be made nearer together, probably $\frac{1}{2}$ in. instead of 1 in., with advantage.

Formula.

If a physical pendulum be constructed capable of vibrating in one plane only, and this plane caused to revolve, the following results ensue:

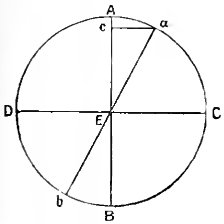


Fig. 1.

In Fig. 1, let $A\ B$ represent such plane, and in which the pendulum is started. On revolving the plane to $C\ D$, the pendulum will stop, or the vibrations be reduced to zero. At any intermediate position, as $a\ b$, the value of original vibration is represented by the component $c\ E$, being diminished by the component $a\ c$. Hence, the value of a vibration of one plane is represented by the cosine of the angle of deviation from the original plane of oscillation.

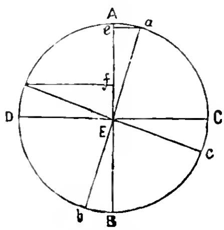


Fig. 2.

Now if a pendulum is free to vibrate in two planes only, at right angles, and these planes capable of revolving, as $A\ B$, $C\ D$, Fig. 2, starting the pendulum in the direction $A\ B$, and revolving the planes to $a\ b$, $c\ d$, the value of the original vibration is, in $a\ b$, as cosine $e\ E$, and, in $c\ d$, as cosine $f\ E$; or, inversely, as the sines $e\ a$ and $f\ d$. Hence, in planes at right angles, the values of a vibration to the two planes are directly as the cosines of the angles of deviation from starting, and inversely as their sines.

In the sine pendulum already described, any deviation from the original plane, *A B*, in which the pendulum is started, is, therefore, shown by the sine, as *e a*, of the angle of deviation. The movement of the index shows this quantity from a state of rest, and, therefore, twice this quantity in a complete vibration.

As it is convenient to have the index shorter than the length of the pendulum, the ratio of their lengths involves a proportion; or, *P* representing the length of the pendulum; *I*, the length of the index; *i*, the indication of index; *v*, the length of entire vibration of pendulum; and *d*, the angle of deviation; we have:

$$P : I :: i : v,\ 2 \sin d;\ \text{or},$$

$$2 \sin d = \frac{I\,i}{P\,v}.$$

When the index is the same length as the pendulum, the equation is simplified thus:

$$2 \sin d = \frac{i}{v};\ \text{or},$$

the indication of index = twice the sine of the angle of deviation.

These statements may be verified by turning the plate, *k* (in diagram), about its central axis, through an angle corresponding to the above sine.

To find the angle of deviation of the pendulum, in any latitude, during a given time. (By Professor L. G. Barbour.)

The following simple equation will serve to verify the results obtainable by the sine pendulum, indicating the rotation of the earth:

$$\text{Sin } \tfrac{1}{2}\, d = \sin \text{lat} \times \sin \tfrac{1}{2} \text{ hour angle}.$$

Thus, in latitude of Richmond, Kentucky, 37° 46′ for one hour.

$$\begin{aligned} &\text{Log sin lat. } 37^\circ\ 46' &&= 9{\cdot}787069 \\ &\text{Log sin } \tfrac{1}{2}\ 15^\circ = 7^\circ\ 30' &&= 9{\cdot}115698 \\ \hline &\text{Log sin } \tfrac{1}{2} \text{ angle } d &&= 8{\cdot}902767 \end{aligned}$$

Or, $4^\circ\ 35' \times 2 = 9^\circ\ 10' = d.$

THE GRAPHICAL METHOD VERSUS THAT BY LEAST SQUARES.

By Henry L. Abbot.

In some recent articles upon the Method of Least Squares, prepared for the Journal of the Franklin Institute by Professor Merriman, of the Sheffield Scientific School, he has selected, as an example, the mean curve of observation given in "The Physics and Hydraulics of the Mississippi," showing the law of change in velocity from surface to bottom in a vertical plane parallel to the current. By applying the method of least squares to the observations, he has deduced new values for the constants of the formula, which give a rather closer accordance than those determined by the graphical method in the original Report. The absolute differences in the two curves, however, are trifling; the largest, which is more than double any of the rest, being only five-thousandths of a foot per second—a quantity too small to be detected by measurement.

Every mathematician, of course, will admit that the method of least squares is the most accurate of any for fixing the values of the constants in such cases, but I cannot agree with Prof. Merriman in characterizing the graphical method as "very unscientific." In my judgment, each of the two methods has its advantages and its disadvantages, and true science requires that the best selection shall be made for the particular case in hand.

The method of least squares is, so to speak, mechanical. It leaves no scope for judgment on the part of the investigator, and any numerical mistake in the long and tedious computation is not readily detected, and may often vitiate the final result. By the graphical method the mind grasps the whole problem; the eye perceives how each given point of the curve deviates from the general law, and if any of them are more doubtful than the others, their weight can be intelligently regulated. In general, I consider that where the data are exact and sufficient, and the labor of computation is warranted by the importance of the result, the method of least squares should have the preference. In other cases, I should use the graphical method.

In this particular case of the grand mean curve of velocity, the method of least squares can advantageously be applied; and if this

curve had been the only problem of the kind under discussion at the time, preference would naturally have been given to the more exact method.

It is not stated in the report, and it probably did not suggest itself to Prof. Merriman in considering the matter, that with so many similar curves to discuss, we could greatly abbreviate the labor of the graphical method. The different curves were all plotted on the same scale on accurate section paper, printed from an engraved stone. One general set of parabolas, which, perhaps, required a couple of hours to compute, was plotted on a piece of tracing paper, with a common vertex. By placing this over a plotted set of observations, a parameter, very closely according with the data, could be taken off at sight. Starting with this, the labor of fitting the curve to the observations was neither excessive nor tedious, and any error of computation was at once detected. Having become habituated to this method, it was naturally used in framing the final equation of the grand mean curve; although in this case it might probably have been better to use the method of least squares. The two results, however, as already stated, do not differ within the limits of measurement.

That we derived great assistance from the general use of the graphical method is incontestable, and I think this will be the experience of any investigator who gives it a fair trial. By no other method are the results so vividly presented to the mind at every step of the study. Indeed, a foreign writer, after discussing many of the old observations made upon the rivers of Europe, and showing graphically that they accord, in a surprising degree, with our new subsurface theory, attributes the failure to discover the law from them to the fact that they had been discussed by a purely mathematical, and not by the graphical, method. The expression, "very unscientific," seems, therefore, rather too sweeping.

I will add that it is a matter of regret that the slight numerical error, in the formula pointed out by Prof. Merriman, had not been discovered before the second edition of "The Physics and Hydraulics of the Mississippi" passed through the press. It should be, as he suggests:

$$V = -0{\cdot}79222\, d_{11}^{\,2} + 3{\cdot}2600,$$

instead of

$$V = -0{\cdot}79222\, d_{11}^{\,2} + 3{\cdot}2611.$$

TENACITY OF METALS AT VARIOUS TEMPERATURES.

Results of a series of experiments recently made in Portsmouth dockyard, with the view of ascertaining what loss of strength and ductility takes place in gun-metal compositions when raised to high temperatures.

The object of making these experiments was to see whether gun-metal would be more or less suitable than cast iron, for making such articles as stop and safety valve boxes, steam pipe connections, fastenings, etc., which might be subjected to high temperatures, either from superheated steam or from being placed in proximity to hot uptakes or funnels. The result of these experiments shows that it is desirable to make further investigations on this important subject. The method adopted for heating the specimens was an oil bath, near the machine for breaking them, the specimens were suspended in the oil out of contact with the vessel containing it, and the dies for gripping them were also so heated; the process of fixing and breaking occupied about one minute, during which care was taken to prevent, as far as possible, loss of heat by radiation and conduction. The recorded temperatures are those of the oil when the specimens were taken out.

In the case of gun-metal, three or more tests were made at each temperature, and the results recorded in the table are the mean, except in a few cases affected by defects in the metal. All the specimens of each composition were run from the same pot in the same manner, *i. e.*, in a horizontal position with a head of $2\frac{1}{2}$ in. to secure uniformity, except those in columns 1 and 2, which were purposely cast separately. It will be observed that those in No. 2 were stronger at the atmospheric temperature than No. 1, and that they suffer sooner by increases of temperature. It may be observed that all the varieties of gun-metal suffer a gradual, but not serious, loss of strength and ductility up to a certain temperature, at which, within a few degrees, a great change takes place, the strength falls to about one-half the original, and the ductility is wholly gone. At temperatures above this point, up to 500 deg., there is little, if any, further loss of strength; the precise temperature at which this great change and loss of strength takes place, although uniform in the specimens

cast from the same pot, varies about 100 deg. in the same composition at different temperatures, or with some varying conditions in the foundry process. The precise temperature at which the change took place in No. 1 series was ascertained to be about 370 deg., and in that of No. 2 at a little over 250 deg. Whatever may be the cause of this important difference in the same composition, the fact stated may be taken as quite certain. The possibility of such a change taking place at a temperature so low in the best gun-metal, used for the more important parts of machinery and boiler mountings, is so important that the point was most carefully tested by repeated experiments at the same temperature, both sorts being heated at the same time in the bath.

Phosphor bronze, the only metal in the series which, from its strength and hardness, could be used as a substitute, was less affected by temperature, and at 500 deg. retains more than two-thirds of its strength and one-third its ductility; when this metal was tested, nothing was known of the difference which may arise from variations in the process of casting, or difference in the quality of the material used, shown in gun-metal, and before adopting it as a substitute for gun-metal this point should be tested for phosphor bronze; and also whether it is possible to harden any of the other compositions without loss of strength.

Rolled Muntz metal and copper are satisfactory up to 500 deg., and may be used as securing bolts with safety.

Wrought irons, Yorkshire and re-manufactured, increase in strength up to 500 deg., but lose slightly in ductility up to 300 deg., where an increase begins and continues up to 500 deg., where it is still less than at the ordinary temperature of the atmosphere. The strength of Landore steel is not affected by temperature up to 500 deg., but its ductility is reduced more than one-half.—*Engineer.*

This is a very important investigation, and the Admiralty deserves much credit for undertaking it, but it is to be regretted that so inexact a method was employed in determining the temperatures.

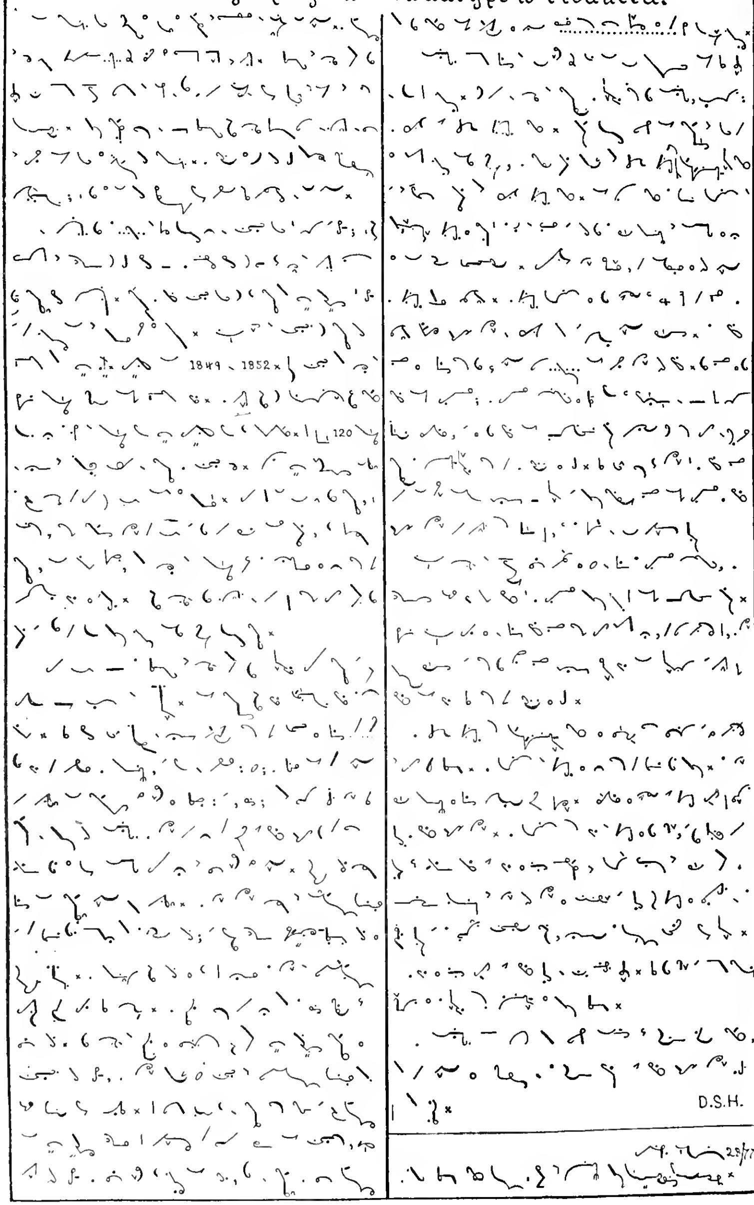
While the recorded temperatures may approximate sufficiently near the exact ones, for the mere comparison of the specimens used in these experiments, yet the uncertainty as to the loss of heat during the time required for fixing and breaking, introduces an error which will prevent a strict comparison between these and other experiments.

Tenacity of Various Metals at Different Temperatures up to 500 Deg. Fahr.—Constant of Machine, 50·25.

Temperature.	Gun-Metal Rods, 1 in. Diameter. 1. Copper, 87·75 Tin, 9·75 Zinc, 2·5		2. 2d set. Copper, 87·75 Tin, 9·75 Zinc, 2·5		3. Copper, 91· Tin, 7· Zinc. 2·		4. Copper, 85· Tin, 5· Zinc, 10		5. Copper, 83· Tin. 2· Zinc, 15·		6. Copper, 92·5 Tin, 5· Zinc, 2·5		Phosphor Bronze Rods, 1 inch Diameter Cop., 92·5 Tin, 7· Phos., ·5		Muntz Metal Rods, ·74 inch Diameter. Cop., 62· Zinc, 38·		Copper Rods, ·72 inch Diameter.		Cast Iron Rods, 1 inch in Diameter. Welsh, ·25 Scotch, ·25 Scrap, ·5		Wrought Iron. Re-manufactured. Rods ·74 in. in Diameter.		Wrought Iron. Yorkshire. Rods ·70 in. in Diameter.		Landore Steel Strips, ·74 inch by ·49 inch.	
	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.	Tensile.	Ductility.
Fahr.	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*	lb.	Per cent.*
Atmospheric deg.	535	12·5	575	8·75	525	16	525	21	485	26	560	20	609	17·5	700	2.5	460	2.5	480	Nil	500	22	460	25	555	26
100	505	10	...	...	525	15·5	550	18	480	26	....	...	614	17	680	2 5	465	2.5	423	"	530	18.75	460	24.25		
150	525	11	...	....	525	14	530	19·5	450	25·5	....	....	610	18	720	3·9	445	4	441	"	530	15				
200	485	10	535	8·75	460	9	523	19	460	26·25	440	11	605	18	685	3·9	440	5	440	"	530	15	465	17·25	535	22·5
250	505	10	385	5	255	3	515	16	440	26	360	6	580	15	670	5	430	7	470	"	540	15				
300	500	10	295	·66	265	Nil	531	18·25	435	23	255	.66	575	12	650	2·5	430	6	490	"	650	15·5	480	7·5	555	11·25
350	450	8·25	295	Nil	....	...	495	17	435	25	....	....	470	7	650	2·25	430	6	470	"	660	12·5				
400	245	·75	....	....	260	Nil	260	2	435	25	...	....	424	5	600	2·25	420	6	401	"	640	12	465	15	590	10·25
450	265	Nil	....	....	....	....	250	2	152	1·2	....	..	380	4	615	3·75	415	6	400	"	680	15				
500	250	"	....	...	275	Nil	230	2	152	Nil	...	...	420	5	620	5	390	6	400	"	680	20	550	13·75	600	10

* In a length of 10in.

How Phonography in Audatype is Produced.



AUDATYPE FOR PRINTING PHONOGRAPHY, AS PRODUCED BY PHOTO-RELIEF PROCESSES.[1]

By D. S. Holman.

In printed phonography there should be found as few as possible of the characteristics of individual handwriting. The forms of the words should be geometrically true, so as to serve as a correct guide for the reader. A description of the means by which this desired end can be accomplished, will be of interest to those who are anxious for a diffusion of a knowledge of the art of phonetic shorthand.

Before proceeding, however, to give a description of these methods, it may be well to allude to some of the ways in which phonography has heretofore been printed. The printing has usually been done by means of transfer lithography; but this has not been satisfactory, for the reason of its resemblance to handwriting. To remedy this, a number of attempts have been made to engrave phonography on metal and stone; but, although the quality of the work so done has been good, the expense has been so great that the amount of reading matter thus produced has been limited. Probably the best engraved phonography was that produced by Mr. Benn Pitman on stone, and which appears in all the books he has published. Another kind of engraving was produced upon copper by Mr. E. Webster, in 1849 to 1852. It was engraved by means of steel punches driven into the copper plates. The writer of this was familiar with this process, having made a set of punches for Mr. Webster, for that purpose. It took 120 punches to make all the combinations necessary to produce the engraved words. Later Mr. Isaac Pitman introduced a beautiful method, which we see now in all his books. We do not know how this is produced, but infer, from the broken lines which now and then are seen in his pages, that it must be produced, in part at least, by means of punches, with which a matrix is made from which the relief plate is obtained.

All these methods thus alluded to are different from the one by which this page, and those which have before appeared in this Journal, have been produced. We now give a description of the

[1] Translation of article printed in audatype on page 428.

methods by which these type plates were produced, and to which we have given the name of audatype.

In the production of these plates, photography plays an important part. It has been found advisable to make the original from which the photograph is taken, much larger than the plate which receives the picture, and for two reasons: First, the defects in the large writing are reduced in proportion as the size is decreased, and second, by the greatly condensed light which is thus brought to bear upon the negative, the lines are made much sharper, and the spaces between them much more opaque than if the negative were made of the same size as the writing. Especial pains must be taken in producing the writing to be reduced. The light lines must be of uniform thickness, and much thicker than can be made by an ordinary pen; and for this work, Holman's audascript pen is especially adapted. The peculiarity of this pen is that it makes a line of uniform width whichever way it is moved. The shades, however, are made by a second tracing with the same pen. This method of shading is similar to that by which Mr. Benn Pitman produces his engraving upon stone: the lines being first engraved of uniform thickness, being afterwards thickened for the shades. It will be evident that to produce the very perfect and beautiful forms in Mr. Benn Pitman's works, it requires much greater skill in the engraver, who must write upon the stone the same size that appears in the print, than to produce the same forms by this process, in which the original is written six or more times as large as it finally appears. The negative can be taken of any size, so as to fit in any publication in which it is desired to have it appear.

There are two methods of producing the type plate from the negative, viz.: the swelled gelatine and the dissolved gelatine processes. Both have been used in the production of the phonography which has appeared in this Journal; the present page being by the dissolved gelatine, or photo-electrotype, process, and all the former pages by the swelled gelatine process.

In the latter process, a thick film of bichromatized gelatine is spread on a sheet of glass, and upon this a sun picture of the negative is made, as in ordinary photographic printing. Wherever the light strikes, which in this case is upon the writing, the gelatine becomes insoluble. The gelatine film is then moistened with cold water, which causes the soluble portions between the lines to swell up

and leave the writing sunken. A plaster cast is taken from this, when the writing will appear in a raised line upon the plaster. This cast is then pressed into wax; the wax impression is dusted over with plumbago to give it a metallic conducting surface, and is then placed in a galvanic bath, remaining there from one to three hours, producing an electrotype plate from which the printing is done. It is found, however, that the lines on the plaster cast are not high enough to make a good type, and before pressing the cast into the wax, the spaces between the lines are routed out, or dug out, with a tool, to any required depth. Another method of accomplishing the same result is first to take the wax impression, the workman afterward building up the spaces on the wax, before putting it into the galvanic bath. Still another way is to take a plaster cast from the one already made, which will reverse it, the lines appearing sunken, and from this last cast to make a stereotype plate in type metal, and rout out the spaces in the plate itself from which the printing is done.

The dissolved gelatine, or photo-electrotype, process is somewhat more simple, and is the reverse of the one just described. The film of gelatine is made very much thicker than before. A light sun picture is taken, leaving sharp outlines. The surface is moistened and the gelatine washed out, slightly deepening the spaces between the lines. The film or plate of gelatine is then dried, and these depressions are filled with an opaque paste, and the plate is again exposed to the full glare of the sun, by which the chemical effect of the light upon the lines is intensified and deepened, so that the gelatine is hardened to a considerable depth and a gradually increasing breadth, making a firm foundation for the type. The plate is again washed and the spaces deepened to any extent desired. It is then dried, and can be printed from directly, as a type plate, or electrotyped as before described.

The negative can also be used in connection with the zinc etching process, by which the writing is transferred to a zinc plate, and the spaces between the lines eaten out by acids.

Sea Sounding.—Sir William Thomson has recently patented an ingenious method of sounding, which can be put in practice without reducing a ship's speed. By the wire-sounding apparatus of the same inventor, a great deal of time is saved, owing to the small amonnt of friction of the sea water on the wire in sinking and in hauling in, as compared with the friction on the rough hemp surface of the lead-line. Owing to the speedy execution of a wire sounding, it was also possible in shallow water to take a series of flying soundings from a ship without slackening her speed as she approached the coast—a great advantage to a mail steamer in thick weather. The new invention of Sir William Thomson measures the depth independently of the wire paid out, which, however, may serve as a check on the other result. The pressure of the sea water at the depth to which the lead sinks, is made the means of registering the depth, in the following way. A glass tube, closed at one end and open at the other, is lined inside with a coloring matter, such as aniline blue, red prussiate of potash, or, better still, chromate of silver, which will be acted upon chemically, and discolored by sea water. This tube, suitably guarded in a brass guard-tube against accidents, is lowered with the lead-line into the sea. The sea water, forcing its way into the tube by the open end, compresses the air-column therein, and mounts up the tube to a height corresponding to the pressure, and discolors the lining of the tube in its passage. The discoloration in the tube marks the height to which the sea water has penetrated, and this becomes a measure of the water pressure, and consequently, by employing a suitable scale, of the depth in fathoms to which the lead was sunk. A chromate of silver lining of the tube is turned from orange yellow to white, by the action of the sea water. Instead of discoloring the lining by sea water alone, the sea water itself may be tinctured by a dye as it enters the tube; or it can be arranged by proper valves simply to trap the water in the tube, and retain it there until it can be brought to the surface and its height read off. The indicator tube and lead-line are used in conjunction with the pianoforte-wire apparatus. Recent trials of this new apparatus on board H. M. S. *Minotaur*, have proved highly satisfactory.—*The Telegraphic Journal.*